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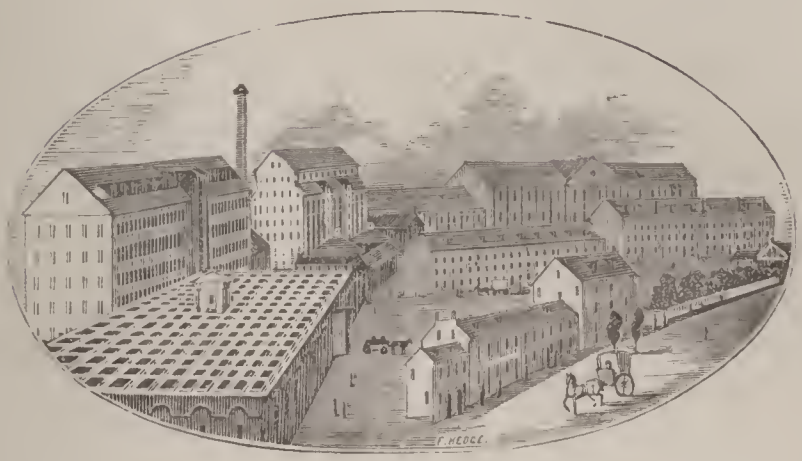
TREATISE

ON THE MANNER OF

Testing Water-Wheels

AND

MACHINERY,



By James Emerson, of Lowell, Mass.

1872.

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INTRODUCTION.

Through the invention of an instrument for testing the power required to drive machinery, I became interested in the testing of Turbine Water-Wheels. Previously, apparatus had been used for that purpose that to me seemed crude and unreliable, while the lack of tables giving the quantity of water flowing over weirs rendered the computations tedious to the initiated and impossible to a large majority of those using wheels; consequently, few of those interested have been able to show the absurdity of the fabulous claims made by interested parties, and for years, confusion has reigned, alike injurious to the users and honest builders of wheels. The object of this little work is to render the subject plain to the most common understanding in theory, while the use of the tables, the past season, in computing the results of more than fifty wheels tested, proves them to be very convenient in saving time and labor to those able to compute the results without them.

To prevent misconception, I would here state that the Swain Wheel is represented in the engraving of Testing Flume simply because that engraving was copied (so far as applicable) from diagrams accompanying report of test of that wheel by H. F. Mills, C. E.; and though all of the Dynamometers represented in this work are inventions of my own, I have no pecuniary interest in any of them, or in any water-wheel, nor am I agent for either.

Persons wishing to purchase Dynamometers, or Gauges, for testing water-wheels, should apply to Fales, Jenks & Sons, Pawtucket, R. I.; and for Water Wheels, to their respective owners.

JAMES EMERSON.

1907

THE WATER-WHEELS OF LOWELL.

[From the Lowell Courier.]

From the gradual increase of the manufacturing establishments dependent for power upon the flow of the Merrimack River at Lowell, it has become a matter of necessity that every possible measure should be taken to economize in the use of water; and this has led to the introduction into our mills of a large number of very superior water-wheels, of an accuracy and delicateness of construction and finish, and yet of such great size and power, that they are probably not excelled, or even equalled, in any part of the world. The removal of the last in the city (except one at the Machine Shop and two or three on the Concord River) of the old-fashioned and unwieldy "breast-wheels" suggests to us that a chapter of information on the hydraulic motors now in use here, and the history of their improvement and adoption, may prove of interest to all the readers of the *Courier* who take a just pride in whatever aids Lowell to substantiate her claim to the title of "the first manufacturing city in America." And first, let us glance at

THE OLD STYLE OF WHEELS,

of which those now being removed from the mills of the Lawrence and Prescott companies are fair examples. These, generally known as "breast-wheels," are dependent for their useful effect simply upon the weight of the water, admitted to the buckets near the top, and retained as long as possible, or until nearly at the bottom of the wheel, where its force is spent and it is discharged. These wheels have in Lowell been constructed of wood, and of

great size, varying in diameter from thirteen to thirty feet, and usually about twelve feet long. Wheels of this class are still in use to a great extent, and in rare instances reach the enormous size of seventy feet in diameter. From the starting of the first mill (Merrimack) in 1823, up to the year 1845, when the number of spindles was about one-half that present running, the breast wheels alone were in use, and were considered the most perfect in all respects of the kinds generally known. But althongh held in such high estimation, they were very extravagant in the use of water; for although the proportion of the useful effect given by the wheel to the power expended sometimes reached as high as seventy-five per cent., the average performance fell far below this point, being only about sixty per cent. And the importance of overcoming this radical defect becoming more and more obvions, improvements were gradnally devised which resulted finally in the invention of a class of wheels known as

TURBINES.

The word turbine is derived from the Latin *turbo*, which means, among other things, a top; and also the whirling or spinning motion of a top. The name, thongh sometimes giving a wider range of meaning, is properly applied to a re-action wheel with vertical axis. The wheel itself is a French invention, dating back to 1830, or thereabouts; and it was introduced into this country several years later by an eminent engineer of Pennsylvania, Mr. Ellwood Morris, who built and put in operation two of these wheels, and published the results of his experiments upon them about the year 1843. The advantages of the turbine were found to be mainly these: a greater economy in the use of water; adaptation to any fall; greater velocity, compactness and durability, and that it was not obstructed by backwater. Since Mr. Morris' experiments there have appeared before the public almost innumerable varieties of turbines, each inventor claiming for his wheel some advantage over all its predecessors; and up to the present time several hundred patents have been granted in this country alone for modi-

fications and alleged improvements of the turbine as first invented. Many of these wheels are quite popular, and are in use in small establishments all over the country; but being roughly and cheaply made, none of them have yet been found to compare with the original Fourneyron turbine as improved by the inventions of Uriah A. Boyden, whose name is familiar to every one who is at all acquainted with the history of our city.

THE "BOYDEN TURBINE."

In 1844 Mr. Boyden designed a seventy-five horse power turbine for the Appleton Company's Picker-house, introducing, as has been said, several changes of his own devising. This wheel was tested immediately after its completion, and found to give a useful effect of seventy-eight per cent. of the power of the water. Encouraged by this success, Mr. Boyden proceeded in 1846 with the construction, for the same company, of three more turbines of one hundred and ninety horse power each, which upon being similarly tested gave the remarkable result of a useful effect of eighty-eight per cent. In experiments since that time results have been obtained as high as ninety-two per cent.; but it is considered that a fair average for these wheels is about seventy-five per cent. against sixty for the breast wheels as above stated. From the date of the Appleton Company's adoption of turbines, they have come rapidly into use; being substituted for the clumsy affairs first used as fast as the latter became unserviceable from wear and decay.

SIZE AND COST.

One of the advantages of the turbine, as already stated, lies in the fact of its occupying so much less space, in proportion to the power, than any other wheel. And this will be more fully realized when it is considered that there are in actual use for manufacturing purposes turbines of only *six inches diameter;* and though these, it must be owned, are rare, those of ten and twelve inches are not unfrequently met with; usually operating, however, in localities where the amount of water is limited while the

fall is considerable. Of the seventy powerful turbines in use in the mills of Lowell, the smallest has a diameter of five, and the largest of eleven feet, and the capacity of a single wheel reaches, in several cases, six hundred and seventy-five horse power.

Most of the wheels of this city have been built at the Lowell Machine Shop; which establishment does an extensive business in this line. The buckets of the wheels, formerly of iron, are now generally made of brass or an alloy called bronze; the object of the change being to keep their surfaces and edges smooth, sharp, and free from corrosion: for it was found that the loss of power from this cause was quite large. The wheel put into the Appleton Picker twenty-four years ago by Mr. Boyden (the same referred to as the first in the city) having been taken out within a year, to make room for a new one, was found to be thickly covered with barnacles, and so completely eaten by rust that great flakes could be scaled from its surface with the fingers.

Few persons have any idea of the amount of labor expended in the construction of one of these wheels, and the consequent cost. Several months are required for building a turbine; and those in the Lowell mills have been purchased at the rate of from ten to eighteen thousand dollars each, for the wheel and its fixtures, exclusive of the cost of penstocks, raceways, pits, etc.

POWER.

The whole power given by the fall of the Merrimack at Lowell, of thirty-three feet, is estimated at about ten thousand horse power, the entire amount of which is already leased to the corporations. In addition to this, there are in the mills thirty-one steam engines, furnishing five thousand horse power additional; and besides these sources there are the three falls of Concord River, the power of which we have no means of estimating.

FOURNEYRON WHEEL.

[Extract from a Treatise on the power of water, by Joseph Glynn.]

M. Fourneyron, who began his experiments in 1823, erected his first turbine in 1827, at Pont sur l'Ognon, in France. The result far exceeded his expectations, but he had much prejudice to contend with, and it was not until 1834 that he constructed another, in Franche Comté, at the iron-works of M. Caron, to blow a furnace. It was of seven or eight horse-power, and worked at times with a fall of only nine inches. Its performance was so satisfactory that the same proprietor had afterwards another of fifty horse-power erected, to replace two water-wheels which, together, were equal to thirty horse-power.

The fall of water was four feet three inches, and the useful effect, varied with the head and the immersion of the turbine, sixty-five to eighty per cent.

Several others were now erected: two for falls of seven feet; one at Inval, near Gisors, for a fall of six feet six inches, the power being nearly forty-horse, on the river Epté, expending thirty-five cubic feet of water per second, the useful effect being seventy-one per cent. of the force employed.

One with a fall of sixty-three feet gave seventy-five per cent.; and when it had the full head or column for which it was constructed—namely, seventy-nine feet—its usual effect is said to have reached eighty-seven per cent. of the power expended.

Another, with one hundred and twenty-six feet, gave eighty-one per cent.; and one with one hundred and forty-four feet fall, gave eighty per cent.

At the instance of M. Arago, a commission of inquiry was instituted by the Government of France, for examining the turbine of Inval, near Paris, the total fall of water being six feet six inches, as has been before mentioned. By putting a dam in the river, below the turbine, so as to raise the tail water, and diminish the head to three feet nine inches, the effect was still equal to seventy per cent.; with the head diminished to two feet, the effect was sixty-four per cent.; and when the head was reduced to ten inches, it gave fifty-eight per cent. of the power expended, notwithstanding the great immersion of the machine.

In the year 1837, M. Fourneyron erected a turbine at St. Blasier (St. Blaise), in the Black Forest of Baden, for a fall or column of water of seventy-two feet (twenty-two mètres). The wheel is made of cast-iron, with wrought-iron brackets; it is about twenty inches in diameter, and weighs about one hundred and five pounds; it is said to be equal to fifty-six horse-power, and to give a useful effect equal to seventy or seventy-five per cent. of the water power employed. It drives a spinning-mill belonging to M. d'Eichtal. A second turbine, at the same establishment, is worked by a column of water of 108 mètres, or three hundred and fifty-four feet high, which is brought into the machine by cast-iron pipes of eighteen inches diameter of the local measure, or about sixteen and one-half inches English. The diameter of the water-wheel is fourteen and one-fourth, or about thirteen inches English, and it is said to expend a cubic foot of water per second; probably the expenditure may be somewhat more than this.

The width of the water-wheel across the pier is .225, or less than a quarter of an inch. It makes from two thousand two hundred to two thousand three hundred revolutions per minute; and on the end of the spindle or upright shaft of the turbine is a bevelled pinion, of nineteen teeth, working into two wheels, on the right and left, each of which has 300 teeth. These give motion to the machinery of the factory, and drive 8,000 water spindles, roving frames, carding engines, cleansers, and other accessories. The useful effect is reported to be from 80 to 85 per cent. of the theoretical water power. The water is filtered at the reservoir before it enters the conduit pipes; and it is important to notice this, since the

apertures of discharge in the wheel are so small as to be easily obstructed or choked.

The water enters the buckets in the direction of the tangent to the last element of the guide-curves, which is a tangent to the first element of the curved buckets. The water ought to press steadily against the curved buckets, entering them without shock or impulse, and quitting them without velocity, in order to obtain the greatest useful effect; otherwise a portion of the water's power must be wasted or expended, without producing useful effect on the wheel.

It is difficult to imagine that a machine so small as this can give motion to the works of a cotton mill on so large a scale. Professor Ruhlmann says, that when he saw it actually doing so, he could not for some time credit the evidence of his senses; and, although he went purposely to examine it, his astonishment prevented him from comprehending, in the first instance, that the fact was really as it appeared.

There are many places, especially in hilly districts, where high falls of water are found, and where the nature of the ground affords facilities for making reservoirs, so as to ensure a constant supply, where the height of the column of water may compensate for the smallness of its volume. In such situations it may be conveyed in pipes to the high-pressure turbine, which may often be applied with advantage for grinding corn, working threshing machines, or for crushing ore, and other purposes. There are other situations in which a great volume of water rolls, with but little fall, and it has been shown that, with a head of only nine inches, the low-pressure turbine has done good service.

THE JONVAL TURBINE.

[From J. E. Stevenson's Circular.]

By referring to our certificate on another page, it will be seen that it is impossible to construct a Turbine greatly to exceed in useful effect a "Jonval," when properly constructed and well finished; and by reference to the table of experiments here inserted, it will be noticed that the efficiency of the Jonval turbine depends not upon the name "Jonval," neither upon the simple fact that one wheel is placed above another—as from six Jonvals tested, but ONE gave 90.77 per cent., that being the one *made by us;* whereas one other gave only 50.34 per cent., the *lowest of all tested.* And why this difference? Simply because one builder knew what he was doing, and the other did not. There are many parties, purporting to manufacture the Jonval Turbine, who state in their circulars that "at a trial of Turbine Wheels, at Fairmount Water Works, at Philadelphia, in 1859 and 1860, the Jonval Wheel gave the highest percentage of all tested"; and they would have the public believe that with their rough, unfinished castings, and guide, and bucket-curves, of whatever form they may happen to be, they give this wonderful result, when none of them possess more than one feature of the Jonval Turbine; and these experiments show that a "Jonval," made by a man of experience, and tested under the most favorable circumstances, gave the *poorest result of all*, simply because he failed in the application of the principles embodied in its construction.

The following is a table of the experiments at the Fairmount Water Works, at Philadelphia, in 1859 and 1860, as taken from the report of the Chief Engineer. The table explains itself.

CERTIFICATE.

DEPARTMENT FOR SUPPLYING THE CITY WITH WATER,
CHIEF ENGINEER'S OFFICE, PHILADELPHIA.

At a trial of water wheels, at Fairmount Works, by order of the Select and Common Council of the City of Philadelphia, a Jonval Turbine, made by "J. E. Stevenson," of Paterson, New Jersey, was tested March 9th, 1860, and produced a co-efficient of useful effect of .8777 per cent. under the following circumstance: 925 pounds were raised 25 feet by 70.25 cubic feet of water under a head and fall of 6 feet. To this must be added the friction of the transmitting machinery, estimated at three per cent., making a total useful effect of .9077 of the power employed.

O. H. P. PARKER,
Chair. of the Water Com.

(SEAL OF CITY.)

HENRY P. M. BIRKINBINE,
Chief Engineer.

In attestation of the above signatures of O. H. P. Parker and Henry P. M. Birkinbine, I set my hand and affix the seal of the City of Philadelphia this 3rd day of April, 1860.

ALEXANDER HENRY,
Mayor of Philadelphia.

TABLE OF EXPERIMENTS.

NAME OF WHEEL.	Kind of Wheel.	Per cent. of effect.	3 per ct. added for friction.	Where built.
Stevenson's 2nd wheel....	Jonval..	.8777	.9077	Paterson, N. J.
Geyelin's 2nd wheel.....	Jonval..	.8210	.8510	Philadelphia, Pa.
Andrews & Kalbach's 3rd wheel.....	Spiral...	.8197	.8497	Bernville, Pa.
Collins' 2nd wheel.....	Jonval..	.7672	.7972	Troy, N. Y.
Andrews & Kalbach's 2nd wheel.....	Spiral...	.7591	.7891	Bernville, Pa.
Smith's Parker's 4th trial..	Spiral...	.7569	.7869	Reading, Pa.
Smith's Parker's 3rd trial..	Spiral...	.7467	.7767	Reading, Pa.
Stevenson's 1st wheel.....	Jonval..	.7335	.7635	Paterson, N. J.
Blake.....	Scroll...	.7169	.7469	East Pepperell, Mass.
Tyler.....	Scroll...	.7123	.7423	West Lebanon, N. H.
Geyelin's 1st wheel.....	Jonval..	.6799	.7099	Philadelphia, Pa.
Smith's Parker's 2nd wheel	Spiral...	.6726	.7026	Reading, Pa.
Merchant's Goodwin	Scroll...	.6412	.6712	Guilford, N. Y.
Mason's Smith.....	Scroll...	.6324	.6624	Buffalo, N. Y.
Andrew's 1st wheel.....	Spiral...	.6205	.6505	Bernville, Pa.
Rich.....	Scroll...	.6132	.6432	Salmon River, N. Y.
Littlepage.....	Spiral...	.5415	.5715	Austin, Texas.
Monroe.....	Scroll...	.5359	.5659	Worcester, Mass.
Collins' 1st wheel	Jonval..	.4734	.5034	Troy, N. Y.

THE WYNKOOP

DOUBLE POWER WATER-WHEEL.

The Wynkoop Wheel consists of two well-known wheels so arranged, one above the other, on separate shafts (one passing through the other) as to be run with the same amount of water required to run either alone. The wheels are called Direct Action and Re-action—the former in the new combination by Mr. Wynkoop making just half the number of revolutions of the latter, but as the wheels are geared in harmony, the whole power of both is given to whatever machinery is to be run. The small amount of water required, as shown by the tables in the Wynkoop pamphlet, the gain in power over all wheels known, (fifty per cent. at least,) as shown by tables of horse-power, and verified at Mr. Parson's Mill, in Saline, make this new improved Wheel one of the great inventions of the day. Indeed, it is so far in advance of other established wheels, that millwrights and hydraulic engineers cannot believe its tables, and so it is obliged to prove its title to favor, step by step, as every other great invention has done before it.

SALINE, Mich., August 25, 1870.

The undersigned, a committee selected to measure the water which was used by a 48 inch Wynkoop Water-Wheel, in Mr. Parson's Mill, found in our experiment, as follows: The waste water which went over a twelve foot weir board was 4¼ in depth, giving 14.7x144=504.72 cubic feet; after opening the gates of the wheel the measurement on the weir-board was 11.2 inches, standing at

that figure for twenty minutes, giving 15.11 x 144=2175 cubic feet, this, minus the waste, 504.72=1671.12 cubic feet used per minute. The head under which the wheel ran was 7 feet 2⅜ inches.

Very respectfully,

EUGENE ROBINSON,
City Surveyor, Detroit.
JOHN E. EDWARDS,
Engineer, Detroit Water Works.
THOS. S. CHRISTIE,
(of Hodge & Christie,) *Engineers and Machinists.*
JAMES W. BARTLETT,
Supt. Detroit Locomotive Works.
JAS. ANDERSON, *Architect, Detroit.*

WYNKOOP WATER-WHEEL CO.:

Gentlemen,—We, the undersigned, acting as a committee to measure the head of water, as set forth in the above certificate, would state that the head was 7 feet 2⅜ inches.

O. BOURKE,
Pres. Board of Education, Detroit.
JAMES B. WAYNE,
Pres. Fulton Iron Works, Detroit.
Hon. S. G. WIGHT.
WM. BARCLAY,
Chair. Board Water Commissioners.
JOSEPH HAND, *Millwright.*
J. HOSMER, *Engineer and Machinist.*

SALINE, Mich., August 25, 1870.

WYNKOOP WATER-WHEEL CO.:

Gentlemen,—We, the undersigned, practical millers, have this day had a trial of the work of a forty-eight inch Wynkoop Water-Wheel, in Mr. Parson's Mill, at Saline, Michigan.

The stone was set by Mr. Delubel, and ground a bushel of new wheat which was very damp, to our entire satisfaction, in two minutes and fifty-five seconds. The wheel takes 170 inches of water, and at the close of the grinding the head was found to be eight feet.

WM. DELUBEL,
JOHN CLEE,
J. W. DAVIS.

DETROIT, Mich., August 26, 1870.

WYNKOOP WATER-WHEEL CO.:

Gentlemen,—We, the undersigned, were present at Mr. Parson's Mill, in Saline, when the above tests of grinding wheat, also, the measurement of water, were made, and know the statements above made to be true.

WM. A. BUTLER, *Banker, Detroit.*
EDWARD KANTER, *Banker, Detroit.*
Hon. N. W. BROOKS.
JOHN PATTON, *Sheriff, Wayne Co.*
ELON W. HUDSON, Esq., *Detroit.*
JOHN B PRICE, Esq., "
H. VONDERHEIDER, Esq., "
ROBERT W. KING, Esq., "
MORRIS WINSOR, Esq., *Chicago.*
GEO. P. WILLIAMS,
Prof. Physics in Michigan University.

The following is the Mill-owner's statement:

SALINE, Washtenaw Co., July 29, 1870.

TO THE PUBLIC:

I take pleasure in saying that some two months since I ordered of the owners one of the Wynkoop Water-Wheels, to be placed in my Flouring Mill, subject to the tables, warrantee, and all the conditions set forth in the pamphlet recently published. After some delay, the wheel was set according to the directions in said pamphlet, under the superintendence of Mr. Wynkoop, and it works entirely satisfactory, running up to the tables, and giving the power and doing the work claimed that it would do in said pamphlet. I have given my order for two more of said wheels, to be delivered as soon as they can be manufactured. I can assure parties wanting wheels, that the Wynkoop Wheel is all the inventor claims for it.

R. W. PARSON, *Owner of Mill.*

Concurred in by

JOSEPH HAND, *Millwright.*

The Miller's statement is as follows:

Mr. H. A. Jewett, of Saline, was engaged to superintend the grinding when the Wynkoop Wheel was started, on account of my being sick; but I saw the flour, and examined it before and after bolting, and it was first class, and the stone ground at the rate of seventeen bushels an hour, with seven feet head—the wheel using 170 practical inches of water. This was on July 29th.

EXTRACT FROM THE TABLED RATE OF A 42-INCH WYNKOOP WHEEL.

Head--Feet.	Cubic feet Discha:ged per Minute.	Revolutions per Minute of Direct Action Wheel.	Revolutions per Minute of Re-action Wheel.	Horse-Power.
10	771	83	166	19.66
11	808	88	176	22.72
12	844	92	188	25.89
13	879	96	192	29.17
14	912	100	200	32.63
15	944	104	208	36.18
16	986	111	222	40.17

ACTUAL PERFORMANCE PER TEST.

No allowance being made for a large quantity of water escaping over the sides of the Pit, the weir being too short for the discharge.

Head.	Cubic feet.	Horse-Power.	Percentage.
10 75	1685.76	21.23	62 07
15.12	2318.23	36.51	55.13

Any one reading the foregoing articles will find little to prove the claims of one better authenticated than the others, unless, indeed, the evidence preponderates in favor of Mr. Wynkoop, who claims that 100 pounds of water used by his device will lift 140 pounds back from whence the 100 started; a little better result, certainly, than claimed by the others, and wheel-builders generally, but differing in degree only, and what might be expected to follow from the extravagant pretensions of the earlier Turbine builders; pretensions that have been the cause of immense damage to manufacturers, through the substitutions of poor Turbines for far better "Breast," or

"Overshot" wheels. That a first-class Turbine is practically superior, under any head, to a Breast wheel there is little reason to doubt; but that it will give a useful effect of 92 per cent. under any circumstances, or that the Fourneyron wheels used at Lowell (running as they do, the most of the time at partial gate) give an average useful effect of 75 per cent., is *very doubtful;* but, the Turbine runs steadier, and at higher speed requires less gearing, is more easily regulated, costs less, is not affected by ice nor back-water, only as to loss of head, takes less room, etc., etc. This only applies to the best Turbines. It is stated that under favorable circumstances M. Fourneyron obtained 87 per cent. with his wheel; and, as Mr. Boyden was only allowed 88—3 per cent. of that being due his Diffuser—it is difficult to understand in what way he improved the percentage of the Fourneyron wheel; and it is also quite as difficult to understand why, of the twelve competitors at the Philadelphia trial, in 1860, seven of which furnished wheels, reported as giving from 74.23 to 90.77 per cent., only one (Tyler) is now known outside of his own town or county, while builders of recent date, whose wheels are tabled considerably below the average rate allowed those seven, are known and are furnishing parties with wheels from Maine to California.

In my Report of Tests (last part of this book) can be seen the results obtained by two Tyler wheels like the one tested at Philadelphia. The two were alike, except one had wrought, the other cast iron buckets.

The one with wrought iron buckets gave - - - 67.10
The one with cast iron buckets gave - - - - - 67.40

about 7 per cent. less than the reported result at Philadelphia; deduct that amount from the others, and their rates would be within the reach of builders of the present day,

though it is doubtful whether a Jonval running on a step can be made to give a useful effect of 82 per cent., there is so much pressure downwards; but, so far as my experience goes, wheels built on that principle run steadier when loaded than those with vertical buckets, operated by the velocity of the water. There is little probability that wheels will ever be made that will practically give more than 80 per cent., but what is wanted is a wheel that will do that at partial as well as at whole gate. Many plans have been tried for that purpose, but, so far, with less favorable results than is desirable.

W. S. Davis, of Contoocook, N. H., has a patent curb for that purpose, (see Report of Tests.) The wheel used in it may have been partially the cause of the experiment proving unsuccessful.

Very favorable results were obtained, the past season, by stopping a number of the guides of a 30-inch Houston wheel with blocks of wood. At whole gate, under 15 feet head, the wheel discharged 1279½ cubic feet of water per minute, giving 29.45 horse-power, and 81.2 per cent. With four of the guides stopped it discharged, under 15.56 feet head, 1016 cubic feet, giving 22.72 horse-power and 76 per cent. With seven, or half of the guides stopped, under 15.73 feet head, it discharged 754 cubic feet, giving 15.76 horse-power and 70 per cent. But, such results are impracticable for daily use, unless the gate can be arranged to operate as the blocks did.

Several builders have constructed wheels with tiers of buckets, or by dividing the usual bucket into three parts, opening the gate one-third, two-thirds, etc., but an excess of buckets has an injurious effect at whole gate. (See Report of Whitney's and Stetson's wheels.) The same result would be likely to follow the division of the

guides, while the wheel is far more likely to become choked with leaves, sticks, eels, etc.

In testing in an open or decked flume I have found so little difference that the circumstances of the particular case would govern me if I were going to construct a flume for manufacturing purposes. It has been thought that a wheel would do better with the whole head of water standing over it than when placed in an "Iron Case," the water entering the side; but in practice I have found nothing to confirm such an opinion, even when the lowest part of the inlet was below the flange of the curb in which the wheel was placed.

In my Report of wheels tested I have stated that there are good reasons for believing that the percentage of a wheel varies with the head under which it is tested. I have figures obtained from the test of a Houston wheel under a low head that give a higher result than obtained by the Risdon wheel at Mount Holly, while experiments with N. F. Burnham's "New Turbine," by D. M. Ettinger, C. E., under 6 feet head, compared with its results at Lowell coincide so nearly with the Risdon tests that they confirm me in that opinion; I am inclined to think, however, that this applies to Direct Action, while the reverse may be the case with the Re-action Wheels; still, it is possible that a wheel is only adapted to *one* head. The point is one of so much importance that, as stated in my Report, I shall immediately construct a Testing Flume for the purpose of effectually deciding it.

DISPUTED POINT.

I have made many experiments with the same wheel, testing it both day and night, but have never found anything to favor the impression that a wheel does more work in the night than in the day-time.

EXPERIMENTING WITH DIFFUSER.

The Risdon 30-inch wheel was tested with a Diffuser made as follows: attached to the bottom of the curb, in which the wheel was placed, there was a tube about 27 inches in length, and 20 inches diameter at the top, and flaring like a trumpet mouth at the bottom; another tube of the same form, but little shorter than the first, 30 inches in diameter, was connected to the curb, leaving an annular space of about five inches between the two, through which the water discharged from the wheel, passed downward, then outward. Result may be found in Report.

BARKER MILL.

As there are many that have never seen the Barker Mill, I will give Mr. Glynn's description of it.

Barker's mill consists of an upright pipe or tube, with a funnel-shaped open top, but closed at the lower end; and from the lower end project two horizontal pipes or arms, also closed at the outer ends, and placed opposite to each other, at right angles with the vertical tube, so as to form a cross. Near to the end of each horizontal pipe, and on one side of it, is a round hole, the two holes being opposite to each other. The upright pipe is mounted upon an axis or spindle, and is kept full of water flowing into the top.

The water, issuing from the holes on the opposite sides of the horizontal arms, cause the machine to revolve rapidly on its axis, with a velocity nearly equal to that of the effluent water, and with a force proportionate to the hydrostatic pressure given by the vertical column, and to the areas of the apertures; for there is no solid surface at the hole on which the lateral pressure can be exerted, while it acts with its full force on the opposite side of the area.

An engraving of it may be seen in my Report, where it is combined with a Fourneyron wheel. The jets of water from the horizontal arms striking the buckets of the

Fourneyron wheel, upon the same principle as of a man standing upon one car and pushing one in an opposite direction, his length, however, is extended between the two in the same space as between one and a fixed, resting point.

FINISHED WHEELS.

There is an impression prevalent that wheels made with polished surfaces will give higher results than those with common finish. I have never tested a polished wheel but where the same person has furnished two or more wheels to be tested. The rough one has in several instances given the highest percentage, and I think there would be little difference if wheels were alike in other respects, whether the surfaces were polished or painted. The Burnham wheel gave a little higher result after the buckets were filed to an edge, and the shaft filed to loosen it in the upper bearing. Easing it in the bearing, I think, was the sole cause of the gain.

In my report, I have stated that a resemblance is no guarantee of merit. The Bastion wheel was designed to be the same as the Houston. Its result may be seen in Report. The last two of that make were made with Wicket Gate placed underneath, in a tube; at part-gate that arrangement proved very injurious.

I am often asked about the size of the canal, flume, or pipe necessary to conduct water to a wheel. I am not good authority upon that point, but think there is little danger of getting the conduit too large. I am informed, however, by one of the most experienced engineers in the country, that water moving four feet per second draws the head down eight inches to the hundred feet; of course, it would be better if its velocity were less, but that answers very well when it is necessary to economize in

outlay. Consequently, a wheel discharging 16 feet per second would be supplied by a conduit with a sectional area of four square feet, or two feet square in the clear. Enlarging, or flaring both ends of the conduit, is supposed to improve it.

RE-INVENTING OLD DEVICES.

I frequently receive circulars with diagrams representing wheels just invented by the sender, which, upon examination, prove to be old and well known. The one tabled in my Report as the Tice wheel may be found represented in the work, previously quoted, by Joseph Glynn. Here is his description of it.

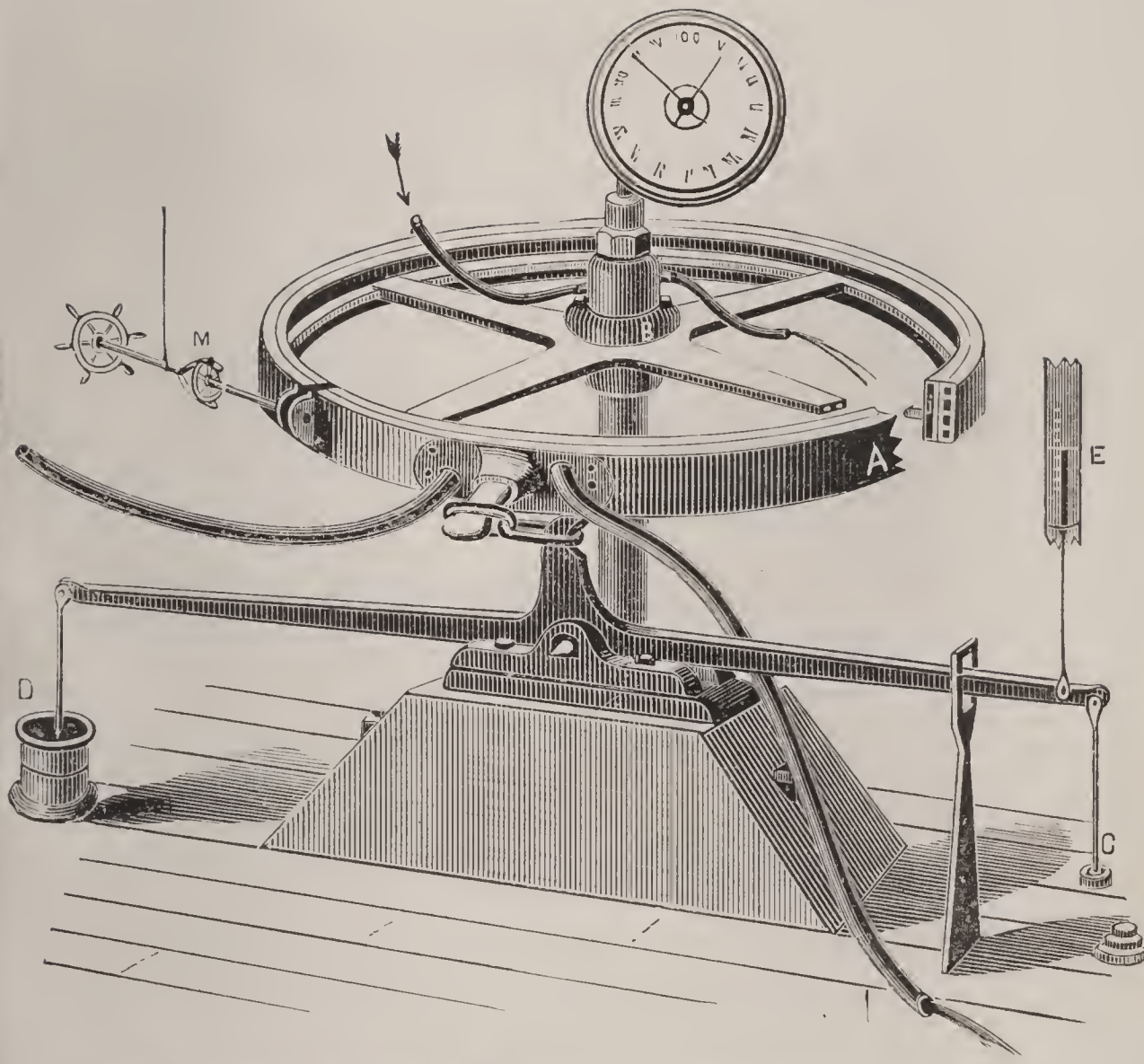
A compact cheap turbine, invented by Mr. Schiele, has recently come into extensive use. It has a high effective working power, and is simple in construction. The water enters at the periphery of the wheel and passes out from the sides, upwards and downwards, without producing so much noise and foam as usually occur with common turbines. This freedom from noise and splashing is an indication that most of the power is taken off from the water. The simplicity of construction facilitates access to, and separation of, the various parts of the wheels. They are well adapted for small work, such as blowing the bellows of organs, working fans for ventilation, printing presses, &c., as they occupy but a small space, and can be placed in any part of a building.

I received a circular from a party in California who had just invented the same; he had tabled it at 98 per cent., and at the head of his tables was the common statement heading the tables of many wheel-builders:

"These tables were calculated expressly for our wheel and are adapted to no other."

Excellent so far as the statement goes, but to complete it properly it should continue, "and perhaps least of all to our own."

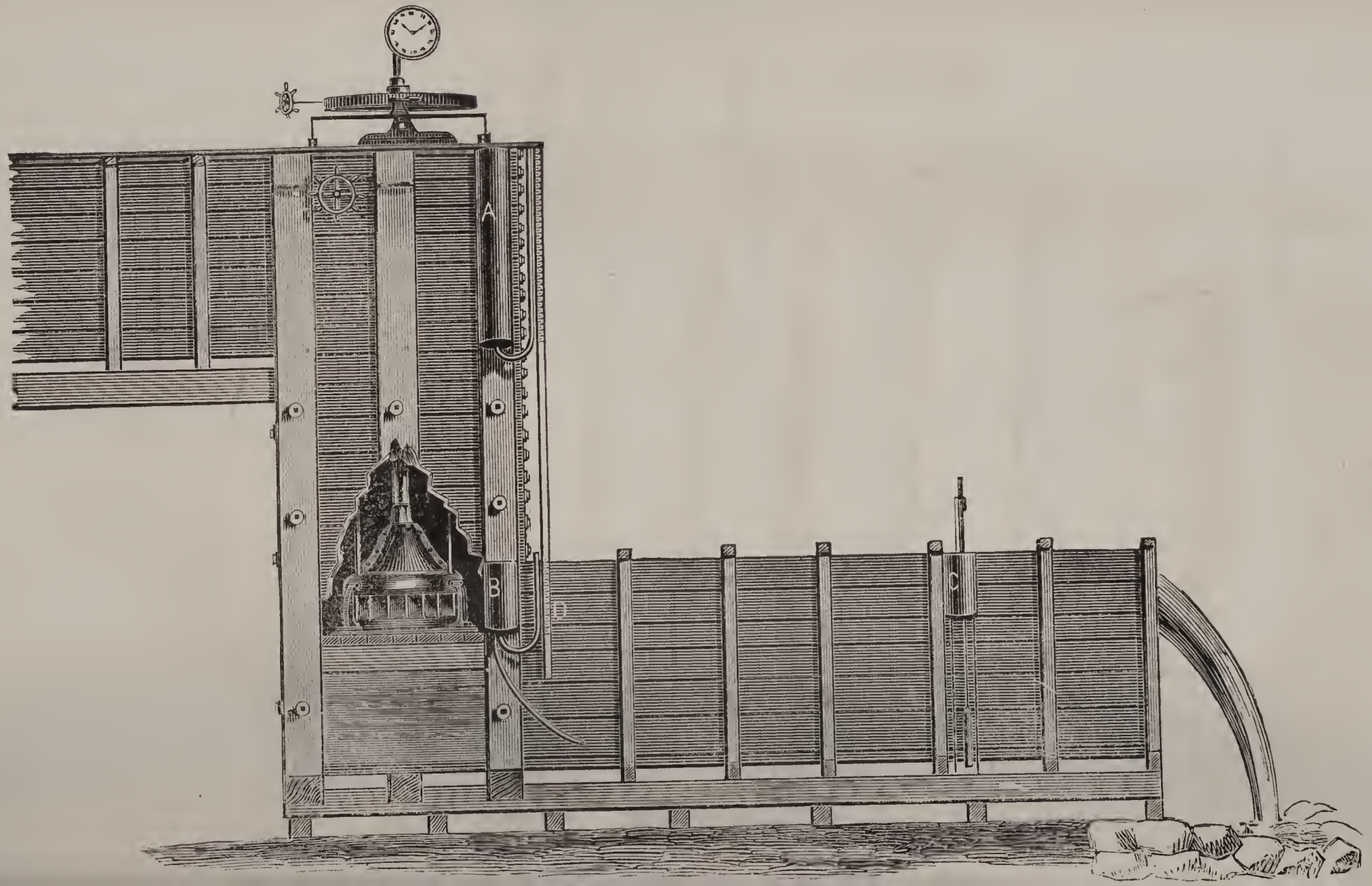
The time has passed for such statements to have much influence—for the users of wheels desire facts instead of fabulous statement—and I will now proceed to describe the manner of determining the exact merits of a wheel.



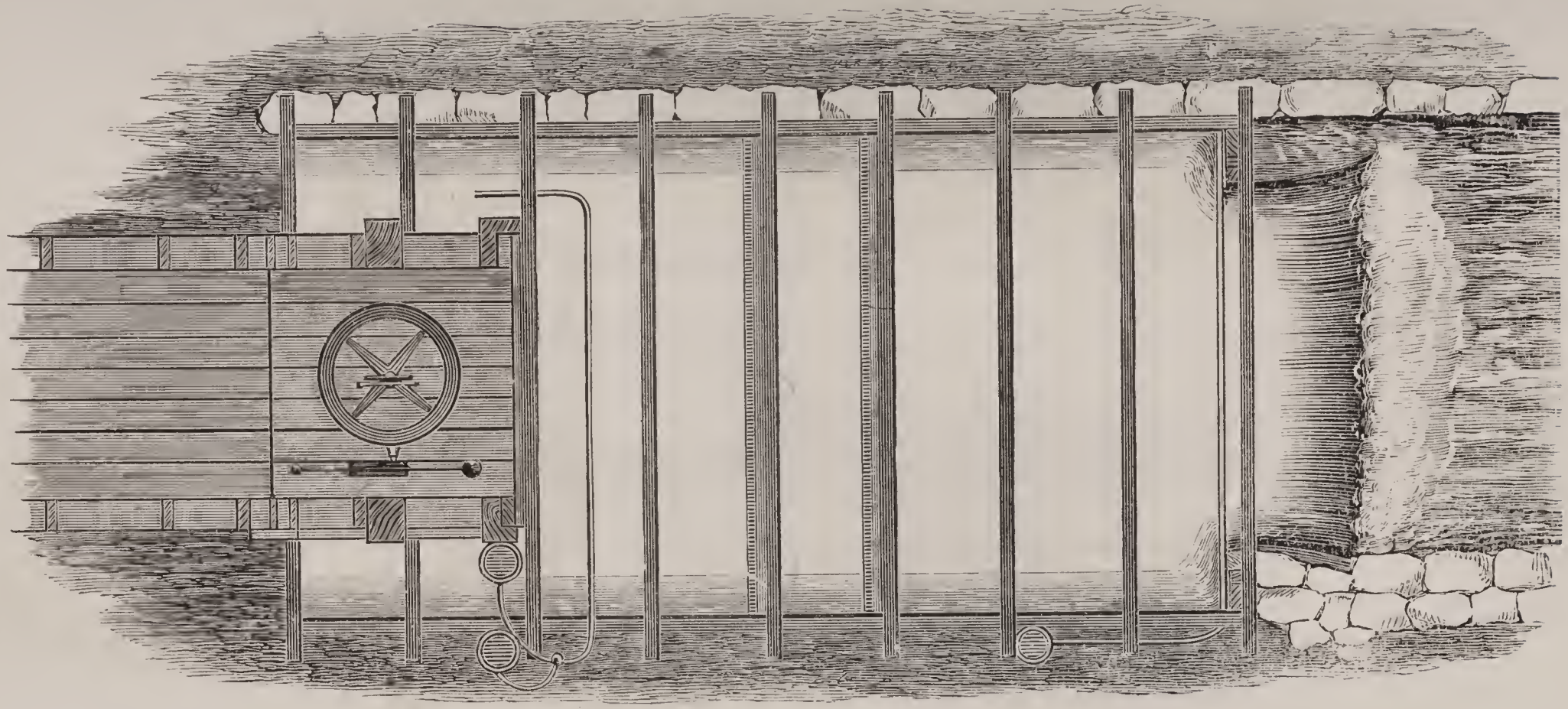
Turbine Dynamometer,

OR

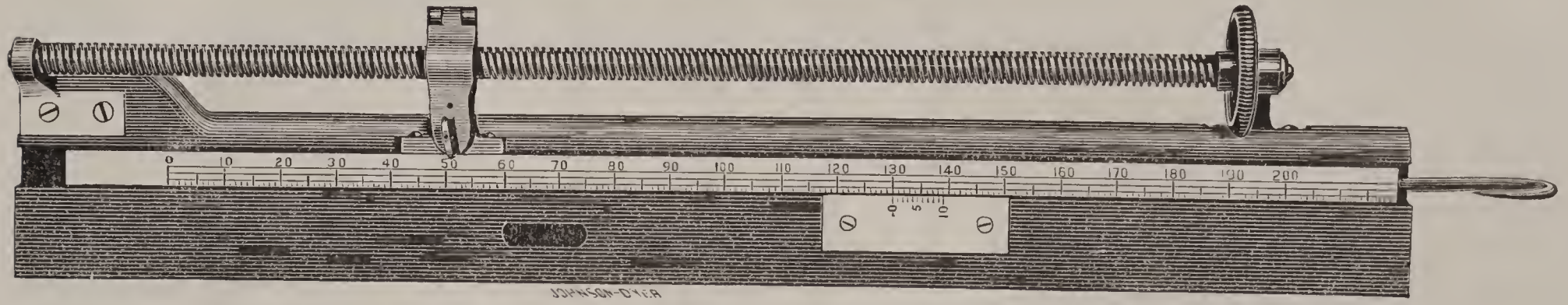
IMPROVED PRONY BRAKE.


A
B
C
D

Testing Flume and Pit.



Hook Guage.



This instrument is absolutely essential where accuracy is required.

DESCRIPTION OF ENGRAVINGS

Representing Testing Flume and Pit.

Through an opening in the side of Forebay may be seen a Turbine wheel with its shaft extending upwards, on the upper end of which, above the Forebay, is secured the instrument for weighing the power transmitted from the water discharged.

To ascertain the useful effect, it is necessary to know the head under which the wheel works, also the quantity of water discharged by it in a given time.

The head is the difference in hight between the surface level of water in the Pit and Forebay when the wheel is running, at which time there is generally too much disturbance in the water to allow of accuracy by direct measurement, thus necessitating the use of the tanks A and B; these are connected to Pit and Forebay by three-quarters inch pipes, through which the water flows so as to equalize the surface of water in tank and source, but too slow to cause ebullition, consequently, the water flows quietly from the lower end of the tanks through the rubber pipes to the glass tubes placed at the side of the measuring pole D. The tank B, however, is not connected directly with the water in the pit, but to the end of a pipe, the other end of which is plugged and bent up stream, partially encircling the wheel. This pipe may be seen in the Plan View, where it is represented as

being above the water, while in fact it rests upon the bottom of the Pit. Along the whole length of this pipe, on its upper side, there are holes one-eighth of an inch in diameter, and sufficient in number to equal the calibre of the pipe. This arrangement is designed to average the depth of water in the pit, to determine the true surface from which to obtain the exact head under which the wheel works. The lower end of the pole D is generally placed level with the crest of the weir, a convenient arrangement, but not essential; all that is necessary is to obtain the exact difference between the true surface of water in Pit and Forebay when the wheel is running.

In the Plan View, another pipe is represented, extending across the Pit just above the weir. This pipe is plugged at one end, has holes along its upper side the same as the one before described, it also rests upon the bottom of the Pit, its open end being connected to the tank C by a rubber pipe. This tank slides up and down on two parallel rods secured close to the side of the Pit—a counterpoise holds the tank at any required hight. The Hook Gauge is firmly fixed to a timber in such a position that the point of the hook will drop in a perpendicular line through the center of the tank, and it will save making corrections for each measurement by placing the point of the hook exactly level with the crest of the weir when the scale of the gauge is standing at zero.

The proper dimensions for a Testing Flume are, of course, determined by the size of wheels to be tested. The Forebay, in diameter, should at least be twice that of any wheel to be placed in it, while the width of the Pit should equal one and a half times the length of the weir; below the crest of which, the depth should equal four times the depth of the stream likely to flow over it. The weir should stand at least twenty feet from the wheel, and at

an exact right angle with the flow of the water. Two racks should be placed between the weir and wheel—the lower one eight feet from the weir. The openings in upper rack should not exceed three-quarters of an inch in width, the lower one not over one-half inch. A Pit suitable to test a four feet wheel should be at least sixteen feet in width and four feet deep below the crest of the weir.

The Dynamometer, or instrument used to determine the power transmitted, is simply an improved "Prony Brake," an engraving of it may be seen on one of the preceding pages. The wheel B is secured to the shaft of the water-wheel, and its speed is controlled by the friction-band A, which is connected to the scale beam as shown, the point of connection describing a circle of a given number of feet. The rim of the wheel and the friction-band are hollow, and kept cool by streams of cold water passing through them; the water in the rim of the wheel being supplied through its hollow arms and the pipe, shown in the engraving. The wheel B is made of cast iron, the friction band of "composition," or "gun metal." The hands of the "counter" are so arranged in connection with a worm gear that they can be made to rotate in the same direction the hands of a clock move, whichever way the wheel being tested may revolve.

The hand wheel for operating the friction band through the screw M has a "Universal Joint," in its shaft, which is arranged with a slide to prevent fraud while testing. The connection of the band with the scale-beam is made by knife-edged links, and the pivot of the beam is also knife-edged. The weights are suspended at one end of the beam as shown at C; at the other end is the "dash-pot," or Hydraulic Regulator D, filled with water to hold the beam steady. The pot is made of cast iron, bored out perfectly true. The plunger on the end of the

rod is a thin disk of iron turned to fit the pot loosely, so as to allow it to move perfectly free; it has six three-eighths inch holes through it stopped with brass thumb screws; one or more of these may be removed at any time to render the beam more sensitive, but the screws must be left lying on the plunger, that the weight may not be changed. To prepare the instrument for testing, the "dash-pot" should be filled with water, the screws removed from the holes in the plunger, but left upon it, the beam leveled with the indicator standing at zero, as shown at E; then place a small weight in the scale pan, and observe the number of seconds required for the weighted end to settle one-half inch; then change the weight to the other end of the beam, the same distance from the fulcrum, and change the balance weight until the beam is balanced; then return the screws to the holes in the plunger, and connect the beam to the friction-band by the links for that purpose.

When testing, I find that the simplest and surest method of obtaining the correct number of revolutions of the wheel, is to hold the hands of the counter at zero until the "timer" is ready; then to run five minutes, and divide by that number to obtain the revolutions per minute.

The hight of water in Forebay and Pit should be noted frequently, and weir readings of Hook Gauge every thirty seconds and the averages used. The most perfect measurement with the Hook Gauge can be obtained by keeping the top of the tank C nearly level with the surface of the water in it, then by looking across it the point of the Hook may be seen the moment it breaks the surface.

In testing a wheel I begin with a light weight, say for a 30-inch wheel under fifteen feet head, start with 100 pounds, run five minutes—the man at the wheel keeping

the beam level—then change to 125 pounds and repeat. Continue to change 25 pounds every five minutes until the speed of the wheel is reduced below its best point, which is reached, we will say, when it is carrying 260 pounds; then reduce the weight to 245 pounds, and change 10 pounds every five minutes until the best point is again passed, which is found, say, when it is carrying 265 pounds; reduce the weight again to, say, 252½ pounds and change the weight 5 pounds at a time every five minutes. Sometimes, when not in a hurry, I commence with 100 pounds and run to 700, or even 800, then, again, I might start, on the same wheel (if I knew about the proper weight for it) say, with 600 pounds, and not change more than 100 during the whole test. Some parties desire to have their wheels tested with as short a range of weights as can be used and the wheel's best speed be found, for the purpose of showing even results through the whole test; but, to the initiated, such results would appear no better than where greater changes were recorded if the weights varied with the speed. Of course, the more the speed of a wheel can be varied without affecting its percentage the better, but that is only determined by using a long range of weights while testing it.

The power transmitted by the wheel is determined as follows: Suppose the scale beam is attached to the friction brake at a point which, if revolving, would describe a circle of twenty feet, and the wheel, running one hundred revolutions per minute, holds the beam at zero when loaded with five hundred pounds. $20 \times 100 = 2000 \times 500 = 1000000 \div 33000$ gives 30.30 H. P.; divide the transmitted power, by the power of the water used, to ascertain the useful effect of the wheel.

Three examples are herewith given for computing results, all in accordance with J. B. Francis' Formula, the

first including the correction for velocity of water approaching the weir, but the two last are sufficiently accurate for all practical purposes where the Testing Pit is constructed according to the dimensions I have given. The examples and tables giving the quantity of water flowing over weirs were prepared by my daughter, assisted by Mr. Wm. S. Southworth. The tables giving velocity of water due various heads were furnished by A. M. Swain.

TEST 17—TYLER WHEEL.

September 21 and 23, 1871. Worked out according to the formula of J. B. Francis.

149.2 Rev. per m.
20 Circumference of circle.

2984.0
300 Lbs.

33000)895200 Foot lbs. (27.13 H. P. of wheel.
66000

235200
231000

42000
33000

90000

Q. per sec.$=3.33(l-0.1nH)H^{\frac{3}{2}}$

1.0615 Height of water on weir.
—.0145 Correction for weir level.

1.0470

1.0470
.2 Number of end contractions × 0.1.

.20940
6.00000 Length of weir.

5.79060=0.7627236
3.33=0.5224442
1.047=0.0199467 } $H^{\frac{3}{2}}$
0.0099733 }
60=1.7781513

1239.48=3.0932391=Q. per min.
15.695=1.1957613=Fall.
62.336=1.7947389=Weight of cubic foot.
33000 (a c)=5.4814861=Horse Power.

36.75=1.5652254=H. P. of water.
27.13=1.4334498=H. P. of wheel.

.7383=1.8682244=Ratio, or, percentage.

The formula for correcting the depth for the velocity of the water approaching the weir is

$$H' = \left[(H + h)^{\frac{3}{2}} - h^{\frac{3}{2}} \right]^{\frac{2}{3}}$$

in which the factor

$$h = \frac{v^2}{2g};$$

v being the velocity found by dividing the Q per second by the section of the stream approaching the weir. As the flume approaching the weir was 14 feet wide, and the bottom of it was 3.5 feet below the crest of the weir, it follows that the area of a section of the stream, when there was 1.047 feet of water flowing over, is 14(3.5+ 1.047)=63.658 square feet.

Q per sec.=20.658=1.3150883
Section=63.658=1.8038530

$\bar{1}.5112353 = v$

2

$\bar{1}.0224706 = v^2$

$\bar{2}.1916296 = 2\ g\ (a\ c)$

.0016=$\bar{3}.2141002 = h$

$\bar{2}.6070501$

.0001=$\bar{5}.8211503 = h^{\frac{3}{2}}$

Then $H+h = 1.047+.0016 = 1.0486$.

1.0486=0.0206099

0.0103049

1.0738=0.0309148=$(H+h)^{\frac{3}{2}}$

Then $(H+h)^{\frac{3}{2}} - h^{\frac{3}{2}} = 1.0738 - .0001 = 1.0737$.

1.0737=0.0308830

0.0102943

1.0486=0.0205887

1.0486=H′=corrected depth on the weir.

Substituting H′ for H in the weir formula first given above, we find the corrected Q to be 1242.25 cubic feet per minute.

1.0486

.2

.20972

6.00000

5.79028=0.7626996

$$
\begin{aligned}
5.79028 &= 0.7626996 \\
3.33 &= 0.5224442 \\
1.0486 &= 0.0206099 \\
0.0103049 & \\
60 &= 1.7781513 \\
\hline
1242.25 &= 3.0942099 \\
15.695 &= 1.1957613 \\
62.336 &= 1.7947389 \\
33000\ (\text{a c}) &= \bar{5}.4814861 \\
\hline
1.5661962 & \\
27.13 &= 1.4334498 \\
\hline
\text{Ratio of useful effect } .7366 &= \bar{1}.8672536
\end{aligned}
$$

Process of finding the Q by the weir table.

Length of weir 6 feet. Depth on the weir 1.0615—the correction 0.145=1.047. There being no quantity for 1.047 it is found by "differences," thus:

The quantity for 1.045 is 1236.02.

The quantity for 1.050 is 1244.68.

Their difference = 8.66. This quantity represents a difference of .005 in H. $\frac{1}{5}$ of 8.66 = the difference for .001, =1.73, $\times$ 2 = 3.46, or the difference for .002. This added to the quantity given for 1.045 = 1239.48. Using this as Q, repeat the logarithmic process used above for finding the H. P. and percentage.

By the common arithmetical process, using the table.

$$\frac{1239.48 \times 15.695 \times 62.336}{33000} = 36.75$$

36.75 = the H. P. of the water. Then the ratio of 27.13 the actual H. P. to 36.75 H. P. is

$$\frac{27.13}{36.75} = 0.7383 =$$

useful effect of the wheel.

```
Example—          1239.48
                    15.695
                    ------
                    619740
                  1115532
                  743688
                 619740
                123948
                ----------
                19453.6386
                     62.336
              ------------
                1167218316
                583609158
               583609158
              389072772
            1167218316
            ------------
33000)1212662.016(36.74 H. P. of water.
      99000
      ------
      222662
      198000
      ------
       246620
       231000
       ------
        156201
36.74)27.130000(.7383 Percentage.
      25718
      -----
       14120
       11022
       -----
        30980
        29392
        -----
         15880
```

Quantities of Water, in cubic feet per minute, flowing over Weirs of different lengths, with varying depths of Water.

Dpth on Weir	LENGTH OF THE WEIR.									
Ft.	**2 Ft**	**3 Ft**	**4 Ft**	**6 Ft**	**7 Ft**	**8 Ft.**	**10 Ft**	**12 Ft**	**16 Ft**	**20 Ft**
0.500	134.22	204.83	275 50	416.78	487.42	558.06	699.34	840.62	1123.18	1405.74
0.505	136 16	207.86	279.57	422.97	494.67	566.38	709.78	853.18	1139.99	1426.80
0.510	138.12	210.85	283 66	429.20	501.97	574.74	720.27	865.81	1156.85	1447.97
0.515	140.08	213.92	287.76	435.45	509.29	583.13	730.82	878.50	1173.87	1469 24
0.520	142 05	216.97	291.89	441.73	516.65	591.57	741.41	891.25	1190.94	1490.62
0.525	144.03	220.03	296.03	448.04	524.05	600.05	752.06	904.06	1208.08	1512.09
0.530	146.01	223.10	300.20	454.38	531.47	608.56	762.75	916.93	1225.30	1533.67
0.535	148.01	226.19	304.38	460.75	538.93	617.12	773.49	929.86	1242.60	1555.34
0.540	150.01	229.28	308.57	467.14	546.43	625.71	781.28	942.85	1259.98	1577.12
0.545	152.01	232 40	312 79	473.56	553.95	634.34	795.12	955.89	1277.44	1598.99
0.550	154.03	235.53	317.02	480.01	561.51	643.01	806.00	969.00	1294.99	1620.97
0.555	156.05	238.66	321.27	486 49	569.10	651.71	816.93	982.16	1312.60	1643.04
0.560	158.08	241.81	325.54	493.00	576.73	660.46	827.92	995.37	1330.29	1665.21
0.565	160.12	244 97	329.82	499.53	584.38	669.24	838.94	1008.65	1348.06	1687.48
0.570	162.16	248.14	334.13	506.09	592.07	678.05	850.02	1021.98	1365.91	1709.84
0.575	164.21	251.33	338.45	512.68	599.79	686.91	861.14	1035 37	1383.84	1732.30
0.580	166.27	254.53	342.78	519.29	607.54	695.80	872.31	1048.82	1401.84	1754.86
0.585	168.34	257.74	347.13	525.93	615.33	704.73	883.52	1062.32	1419.91	1777.51
0.590	170.41	269 96	351.50	532.60	623.14	713.69	894.78	1075.88	1438.07	1800.25
0.595	172.49	264.19	355.89	539.29	630.99	722.69	906.09	1089.49	1456.29	1823.09
0.600	174.57	267.43	360.29	546.01	638.87	731.73	917.44	1103.16	1474.60	1846.03
0.605	176.67	270.69	364.71	552.76	646.78	740.80	928.84	1116.88	1492.97	1869.06
0 610	178.77	273.96	369.15	559.53	654.72	749.91	940.28	1130.66	1511.42	1892.18
0.615	180.87	277.23	373.60	566.32	662.68	759.05	951.77	1144.50	1529.95	1915.40
0.620	182.99	280.53	378.07	573.15	670.68	768.23	963.31	1158.39	1548.55	1938.71
0.625	185.10	283.83	382.55	579.99	678.72	777.44	974.88	1172.33	1567.22	1962.11
0.630	187.23	287.14	387.05	586.87	686.78	786.69	986.50	1186.32	1585.96	1985.60
0 635	189.36	290.46	391.56	593.77	694.87	795.97	998.17	1200.37	1604.78	20 9.18
0.640	191.50	293.80	396.10	600.69	702.99	805.29	1009.88	1214.48	1623.67	2032.86
0.645	193.65	297.14	400.64	607.64	711.14	814.64	1021.64	1228.63	1642.63	2056.62
0.650	195.80	300.50	405.21	614.62	719.32	824.02	1033.43	1242.81	1661.66	2080.48
0.655	197.95	303.87	409.78	621.61	727.53	833.44	1045.28	1257.10	1680.76	2104.42
0.660	200.12	307.25	414.38	628.64	735.77	842.90	1057.10	1271.42	1699.94	2128.46
0.665	202.29	310.64	418.99	635.69	744.04	852.39	1069 69	1285.79	1719.19	2152.58
0.670	.....	314.01	423.61	642.76	752 34	861.91	1081.06	1300.21	1738.50	2176.80
0.675	.....	317.45	428.25	649.86	760.66	871.47	1093.07	1314.68	1757.85	2201.10
0.680	.....	320.87	432.91	656.98	769.02	881.06	1105.13	1329.20	1777.34	2225.49
0.685	.....	324.30	437.58	664.13	777.40	890.68	1117.22	1343.77	1796.87	2249.97
0.690	.....	327.75	442 26	671.30	785.81	900.33	1129.36	1358.40	1816.46	2274 53
0.695	.....	331.20	446.96	678.49	794.26	910.02	1141.55	1373.07	1836.13	2299.18
0.700	.....	334.66	451.69	685.71	802.72	919.71	1153.77	1387.80	1855.80	2323.92
0.705	..... .	338.14	456.41	692.95	811.22	929.49	1166.04	1402.58	1875.66	2348.75
0.710	.....	341.62	461.15	700.22	819 75	939.28	1178 31	1417.41	1895.53	2373.66
0.715	.....	345.12	465.91	707.50	828.30	949.10	1190.69	1432.28	1915.47	2398.66
0.720	.....	348.62	470.69	714.82	836.88	958.95	1203.08	1447.21	1935.48	2423.74
0.725	.....	352.13	475.47	722.15	845.49	968.83	1215.51	1462.19	1955.55	2448.91
0.730	.....	355.66	480.28	729.51	854.13	978.75	1227.98	1477.22	1975.69	2474.16
0.735	.....	359.19	485.09	736.89	862.79	988 69	1240.49	1492.30	1995.90	2499.50
0.740	.....	362.74	489.92	744.30	871.49	998.67	1253.05	1507.42	2016.17	2524.92
0.745	.....	366.29	494.77	751.73	880.21	1008.68	1265.64	1522.60	2036.51	2550.42
0.750	.....	369.86	499.63	759.18	888.95	1018.73	1278.27	1537.82	2056.92	2576.01
0.755	.....	373.43	504.50	766.65	897.72	1028.80	1290.95	1553.09	2077.39	2601.68
0.760	.....	377.01	509.39	774.15	906.52	1038.90	1303.66	1568.42	2097.93	2627.44
0.765	.....	380.61	514.29	781.67	915.35	1049.04	1316.41	1583.78	2118.53	2653.28
0.770	..... .	384.21	519.21	789.21	924.21	1059.20	1329.20	1599.20	2139.20	2679.20
0.775	.....	387.82	524.14	796.77	933.09	1069.40	1342.03	1614.67	2159.93	2705.20

D'pth on Weir.	LENGTH OF THE WEIR.								
Ft.	3 Ft.	4 Ft.	6 Ft	7 Ft.	8 Ft.	10 Ft.	12 Ft.	16 Ft.	20 Ft.
0.780	391.44	529.08	804.35	941.99	1079.63	1354.91	1630.18	2180.73	2731.28
0.785	395.07	534.04	811.96	950.93	1089.89	1367.82	1645.74	2201.59	2757.45
0.790	398.71	539.01	819.59	959 88	1100.18	1380.70	1661.35	2222.52	2783.69
0.795	402.36	543.99	827.24	968.87	1110.50	1393.75	1677.00	2243.51	2810.02
0.800	406.02	548.99	834.92	977.88	1120.85	1406.78	1692.71	2264.57	2836.43
0.805	409.69	554.00	842.61	986.92	1131.23	1419.84	1708.46	2285.69	2862.92
0.810	413.37	559.02	850.33	995.98	1141.64	1432 95	1 24.25	2306.87	2889.49
0.815	417.05	564.06	858.07	1005.07	1152.08	1446 09	1740.10	2328.12	2916.14
0.820	420.75	569.11	865 83	1014 19	1162.55	1459.27	1755.99	2349.43	2942.87
0.825	424.45	574.17	873.61	1023.33	1173 05	1472.48	1771.92	2370.80	2969.67
0.830	428.17	579.25	881.41	1032.49	1183.58	1485.74	1787.90	2392.23	2996.56
0.835	431.89	584.34	889.24	1041 69	1194.13	1499.03	1803.93	2413.73	3023.53
0.840	435.62	589.44	897.08	1050.90	1204.72	1512.36	1820.09	2435.29	3050.57
0.845	439.36	594.56	904.95	1060.14	1215 34	1525.73	1836.12	2456 91	3077.69
0.850	443.11	599.68	912.84	1069.41	1225.99	1539.14	1852.29	2478.59	3104.89
0.855	446.87	604.83	920.74	1078.70	1236.66	1552.58	1868.50	2500.33	3132.17
0.860	450.63	609.98	928.67	1088.02	1247.37	1566.06	1884.75	2522.14	3159.53
0.865	454.41	615.15	936.62	1097.36	1258.10	1579.58	1901.05	2544.01	3186.96
0.870	458.19	620.33	944.59	1106.73	1268.86	1593.13	1917.40	2565.93	3214.47
0.875	461.98	625.52	952.58	1116.12	1279.65	1606.72	1933.79	2587 92	3242.06
0.880	465.78	630.72	960.60	1125.53	1290.47	1620.35	1950.22	2609.97	3269.72
0.885	469.59	635.94	968.63	1134.97	1301.32	1634 01	1966 70	26 2.08	3297.46
0.890	473.41	641.17	976.68	1144.44	1312.19	1647.71	1983.22	2654.25	3325.28
0.895	477.24	646.41	984.75	1153.93	1323.10	1661.44	1999.80	2676.48	3353.17
0.900	481.07	651.66	992 85	1163.44	1334.03	1675.22	2016.40	2698.77	3381.14
0.905	484.91	656.93	1000.96	1172.98	1344.99	1689.02	2033.05	2721.12	3409.18
0.910	488.76	662.21	1009.09	1182.54	1355.98	1702.87	2049.75	2743 53	3437.30
0.915	492.62	667.50	1017.25	1192.12	1367.00	1716.75	2066.49	2765.99	3465.49
0.920	496.49	672.80	1025.42	1201.73	1378.04	1730.66	2083.28	2788.52	3493.76
0.925	500 36	678.12	1033.61	1211.36	1389.11	1744.61	2100.11	2811.11	3522.10
0.930	504.25	683.44	1041.82	1221.02	1400.21	1758.60	2116.98	2833.75	3550.52
0.935	508 14	688.78	1050.06	1230.70	1411.34	1772.62	2133.90	2856.45	3579.01
0.940	512.04	694.13	1058.31	1240.40	1422.49	1786.67	2150.85	2879.22	3607.58
0.945	515.95	699.49	1066.58	1250.13	1433.67	1800.76	2167.85	2902.03	3636.22
0.950	519.86	704.87	1074.87	1259.88	1444.88	1814.89	2184.90	2924.91	3664.93
0.955	523.78	710.25	1083.18	1269.65	1456.11	1829.05	2201.98	2947.85	3693.71
0.960	527.71	715.65	1091.51	1279.45	1467.38	1843.24	2219.11	2970.84	3722 57
0.965	531.65	721.06	1099.86	1289.27	1478.67	1857.47	2236.28	2993.89	3751.50
0.970	535.60	726.48	1108.23	1299.11	1489.98	1871.74	2253.49	3017.00	3780 50
0.975	539.55	731.91	1116.62	1308.97	1501.33	1886.04	2270.74	3040.16	3809.58
0.980	543.52	737.35	1125.02	1318.86	1512.70	1900.37	2288.04	3063.39	3838.73
0.985	547.49	742.81	1133.45	1328.77	1524.09	1914.74	2305.38	3086 66	3867.95
0.990	551.46	748.27	1141.89	1338.70	1535.52	1929.14	2322.76	3110.00	3897.24
0.995	555.45	753.75	1150.36	1348.66	1546.96	1943.57	2340.18	3133.39	3926.60
1.000	559.44	759.24	1158.84	1358.64	1558.44	1958.04	2357.64	3156.84	3956.04
1.005	.....	.....	1167.34	1368.64	1569.94	1972.54	2375.14	3180.34	3985.55
1.010	.....	.....	1175.86	1378.66	1581.47	1987 08	2392.69	3203.90	4015.12
1.015	.....	.....	1184.40	1388.71	1593.02	2001.65	2410.27	3227.52	4044.77
1.020	.....	.....	1192.95	1398.78	1604.60	2016.25	2427.90	3251.19	4074.49
1.025	.....	.....	1201.53	1408.87	1616.21	2030.89	2445 56	3274.92	4104.28
1.030	.....	.....	1210.12	1418.98	1627.84	2045.56	2463.27	3298.70	4134.14
1.035	.....	.....	1218.74	1429.12	1639.50	2060.26	2481.02	3322 54	4164.07
1.040	.....	.....	1227.37	1439.27	1651.18	2074.99	2498 81	3346.44	4194.06
1.045	.....	.....	1236.02	1449.45	1662.89	2089.76	2516.64	3370.38	4224.13
1.050	.....	.....	1244.68	1459.65	1674.62	2104.56	2534.51	3394.39	4254.27
1.055	.....	.....	1253.36	1469.87	1686.38	2119.40	2552.41	3418.45	4284.48
1.060	.....	.....	1262.07	1480.12	1698.17	2134.26	2570.36	3442 56	4314.75
1.065	.....	.....	1270.79	1490.38	1709.98	2149.16	2588.35	3466.73	4345.10
1.070	.....	.....	1279.53	1500.67	1721.81	2164.10	2606.38	3490.95	4375.51
1.075	.....	.....	1288.28	1510.98	1733.67	2179.06	2624.45	3515.22	4406.00

D'pth on Weir.	LENGTH OF THE WEIR.								
Ft.	3 Ft.	4 Ft.	6 Ft	7 Ft.	8 Ft.	10 Ft.	12 Ft.	16 Ft.	20 Ft.
1.080	.....	.....	1297.06	1521.31	1745,56	2194.06	2642.55	3539.55	4436.55
1.085	.....	.....	1305.85	1531 66	1757.47	2209.08	2660.70	3563 93	4467.17
1.090	.....	.....	1314.66	1542.03	1769.40	2224.14	2678 89	3588.37	4497.85
1.095	.....	.....	1323.49	1552.42	1781.36	2239.24	2697 11	3612 86	4528.61
1.100	.....	.....	1332.33	1562.84	1793 35	2254.36	2715 37	3637.40	4559.43
1.105	.....	.....	1341.19	1573.27	1805.36	2269.52	2733.68	3662.00	4590 32
1.110	.....	.....	1350.07	1583.73	1817.39	2284.70	2752.02	3686.65	4621.28
1.115	.....	.....	1358.97	1594.21	1829.45	2299.92	2770.40	3711.35	4652.31
1.120	.....	.....	1367 89	1604.71	1841.53	2315.17	2788.82	3736 11	4683.40
1.125	.....	.....	1376.82	1615.23	1853.64	2330 46	2807.28	3760.92	4714.56
1.130	.....	.....	1385.77	1625 77	1865.77	2345.77	2825 77	3785.78	4745.78
1.135	.....	.....	1394.73	1636.33	1877.92	2361.12	2844.31	3810.69	4777.07
1.140	.....	.....	1403.72	1646.91	1890.10	2376.45	2862 88	3835.66	4808.43
1.145	.....	.....	1412.72	1657.51	1902.31	2391.90	2881.49	3860.67	4839.85
1.150	.....	.....	1421.73	1668.13	1914.53	2407.34	2900.14	3885.74	4871.34
1.155	.....	.....	1430.77	1678.78	1926.79	2422.81	2918.83	3910.86	4902.90
1.160	.....	.....	1439.82	1689.44	1939.06	2438.31	2937.55	3936.04	4934.52
1.165	.....	.....	1448 89	1700.12	1951.36	2453.84	2956.31	3961.26	4966.21
1.170	.....	.....	1457.97	1710.83	1963.68	2469 40	2975.11	3986.54	4997.96
1.175	.....	.....	1467.07	1721 55	1976.03	2484.99	2993.45	4011.86	5029.78
1.180	.....	.....	1476.19	1732.30	1988.40	2500.61	3012.82	4037.24	5061.66
1.185	.....	.....	1485.33	1743.06	2000.80	2516.27	3031.73	4062.67	5093.61
1 190	.....	.....	1494.48	1753.84	2013.21	2531.93	3050 68	4088.15	5125.63
1.195	.....	.....	1503.64	1764.65	2025.65	2547.66	3069.67	4113.69	5157.70
1.200	.....	.....	1512.83	1775.47	2038.12	2563.40	3088 69	4139.27	5189.84
1.205	.....	.....	1522.03	1786.32	2050.60	2579.18	3107.75	4164.90	5222.05
1.210	.....	.....	1531.25	1797.18	2063.11	2594.98	3126.85	4190.59	5254.32
1.215	.....	.....	1540.48	1808.06	2075.65	2610.82	3145.98	4216.32	5286 65
1.220	.....	.....	1549.73	1818.97	2088.20	2626.68	3165.15	4242.10	5319 05
1.225	.....	.....	1559.00	1829.89	2100.78	2642.57	3184.36	4267.94	5351.51
1.230	.....	.....	1568.28	1840 83	2113.39	2658.50	3203.60	4293.82	5384.04
1.235	.....	.....	1577.58	1851.79	2126.01	2674.45	3222.88	4319.76	5416.63
1.240	.....	.....	1586.89	1862.78	2138.66	2690.42	3242.20	4345.74	5449.28
1.245	.....	.....	1596.22	1873.78	2151.33	2706.44	3261.55	4371.77	5482.00
1.250	.....	.....	1605.57	1884.80	2164.02	2722.48	3280.94	4397.86	5514.77
1.255	.....	.....	1614.93	1895 83	2176.74	2738.55	3300.36	4423.99	5547.61
1.260	.....	.....	1624 31	1906.89	2189.48	2754.65	3319.82	4450.17	5580.51
1.265	.....	.....	1633.70	1917.97	2202.24	2770.78	3339.32	4476.40	5613.47
1.270	.....	.....	1643.11	1929.07	2215.02	2786.94	3358.85	4502.68	5646.51
1.275	.....	.....	1652.54	1940.18	2227.83	2803.13	3378.42	4529.01	5679.60
1.280	.....	.....	1661.98	1951.32	2240.66	2819.34	3398.02	4555.39	5712.75
1.285	.....	.....	1671.43	1962.47	2253.51	2835.59	3417.66	4581.82	5745.97
1.290	.....	.....	1680.90	1973.64	2266.38	2851.86	3437.34	4608.29	5779.25
1.295	.....	.....	1690.39	1984.83	2279.28	2868.16	3457.05	4634.82	5812.58
1.300	.....	.....	1699.90	1996.05	2292.20	2884.49	3476.79	4661.39	5845.98
1.305	.....	.....	1709.41	2007.27	2305.13	2900.85	3496.57	4688.01	5879.44
1.310	.....	.....	1718.95	2018.52	2318.09	2917.24	3516.39	4714.68	5912.97
1.315	.....	.....	1728.50	2029.79	2331.08	2933.66	3536.24	4741.40	5946.55
1.320	.....	.....	1738.06	2041.07	2344.08	2950 10	3556.12	4768.16	5980.20
1.325	.....	.....	1747.64	2052.38	2357.11	2966.57	3576.04	4794.97	6013.90
1.330	.....	.....	1757.24	2063.70	2370.16	2983.07	3595.99	4821.83	6047.67
1.335	.....	.....	1766.85	2075.04	2383.23	2999.61	3615.98	4848.74	6081.50
1.340	.....	.....	1776.47	2086.40	2396.32	3016.17	3636.01	4875.70	6115.38
1.345	.....	.....	1786.11	2097.77	2409.43	3032.75	3656.06	4902.70	6149.33
1.350	.....	.....	1795.77	2109.17	2422.57	3049.36	3676.16	4929.75	6183.34
1.355	.....	.....	1805.44	2120.58	2435.72	3066.00	3696.28	4956.85	6217.41
1.360	.....	.....	1815.13	2132.01	2448.90	3082.67	3716.45	4983.99	6251.54
1.365	.....	.....	1824.83	2143.46	2462.10	3099.37	3736.64	5011.19	6285.73
1.370	.....	.....	1834.54	2154.93	2475.32	3116.10	3756.87	5038.42	6319.98
1.375	.....	.....	1844.27	2166.42	2488.56	3132.85	3777.13	5065.71	6354.28

D'pth on Weir	LENGTH OF THE WEIR.								
Ft.	3 Ft.	4 Ft.	6 Ft.	7 Ft.	8 Ft.	10 Ft.	12 Ft.	16 Ft.	20 Ft.
1.380	.....	.....	1854.02	2177.92	2501 82	3149.63	3797.43	5093.04	6388.65
1.385	.....	.....	1863.78	2189.44	2515.11	3166.45	3817.76	5120.42	6423.08
1.390	.....	.....	1873.55	2200.98	2528.41	3183.27	3838.13	5147.84	6457.56
1.395	.....	.....	1883 34	2212.54	2511.74	3200.13	3858.53	5175.32	6492.11
1.400	....	.....	1893.14	2224.11	2555.08	3217.02	3878.96	5202.83	6526.71
1.405	.....	.....	1902.96	2235.71	2568.45	3233.94	3899.42	5230.40	6561 37
1.410	.....	.....	1912.79	2247.32	2581.84	3250.88	3919.92	5258.01	6596.10
1.415	.....	.....	1922.64	2258.94	2595.25	3267.85	3940.46	5285.67	6630.87
1 420	.. ...	.....	1932.50	2270.59	2608.68	3284 85	3961.02	5313.37	6665.71
1.425	.....	.....	1942.38	2282.25	2622.13	3301.87	3981.62	5341.12	6700 61
1.430	.....	.....	1952.27	2293.93	2635.60	3318.95	4002.25	5368.9.	6735.57
1.435	.....	.....	1962.17	2305.63	2649.09	3336.01	4022.92	5396.75	6770.58
1.440	.. ..	.....	1972.09	2317.35	2662.60	3353.11	4043.62	5424.64	6805.65
1.445	.....	.....	1982.02	2329.08	2676.13	3370 24	4064.35	5452.57	6840.79
1.450	.....	.....	1991.97	2340.83	2689.69	3387.40	4085.12	5480.54	6875.97
1.455	.....	.....	2001.93	2352.60	2703.26	3404.59	4105.91	5508.56	6911.21
1.460	.....	.....	2011.91	2364.38	2716.85	3421 80	4126.74	5536.63	6946.52
1.465	.....	.....	2021.90	2376.18	2730.47	3439.04	4147.61	5564.74	6981 88
1.470	.....	.....	2031.90	2388.00	2744.10	3456.30	4168.50	5592.90	7017.30
1.475	... .	.....	2041.92	2399.84	2757.76	3473.59	4189 43	5621.10	7052.77
1.480	.....	.....	2051.95	2411.69	2771.43	3490.91	4210.39	5649.35	7088.30
1.485	.....	.....	2062.00	2423.56	2785.13	3508.26	4231.38	5677.64	7123.90
1.490	.....	.....	2072.06	2435.45	2798.84	3525.63	4252.41	5705.97	7159.54
1.495	.....	.....	2082.13	2447.35	2812.58	3543.02	4273.47	5734.35	7195.24
1.500	.....	.....	2092.22	2459.28	2826.33	3560.44	4294.56	5762.78	7231.00
1.505	.....	.....	.....	2471.21	2840.11	3577.89	4315.68	5791.25	7266.82
1.510	.....	.....	.....	2483.17	2853.90	3595.36	4336.83	5819.76	7302.69
1.515	.....	.....	.....	2495.14	2867.71	3612.86	4358.02	5848.32	7338 62
1.520	.....	.....	.....	2507.13	2881.55	3630.39	4379.23	5876.92	7374.61
1.525	.....	.....	.....	2519.13	2895.40	3647.94	4400.48	5905.56	7410.65
1.530	.....	.....	.....	2531.15	2909.28	3665.52	4421.76	5934.25	7446.74
1.535	... ..	.. ...	.....	2543.19	2923.17	3683.12	4443.08	5962.99	7482.90
1.540	.....	.....	.....	2555.24	2937.08	3700 75	4464.42	5991.77	7519.11
1.545	.....	.....	. ....	2567.32	2951.01	3718.41	4485 80	6020.59	7555.37
1.550	.... .	.....	.....	2579.40	2964.96	3736.09	4507.21	6049.45	7591.69
1.555	.....	.....	.....	2591.51	2978.93	3753.79	4528.65	6078.36	7628.07
1.560	.....	.....	.....	2603.63	2992 92	3771.52	4550.12	6107.31	7664.50
1.565	.....	.....	.....	2615.76	3006.93	3789.28	4571.62	6136.30	7700.99
1.570	.....	.....	.....	2627.92	3020.96	3807.06	4593.15	6165.34	7737.53
1.575	.....	.....	.....	2640.08	3035.01	3824.86	4614.72	6194.42	7774.13
1.580	.....	.....	.....	2652.27	3049.08	3842.69	4636.31	6223.55	7810.78
1.585	.....	.....	.....	2664.47	3063.16	3860.55	465 .94	6252.71	7847.49
1.590	.....	.....	.....	2676.69	3077.27	3878 43	4679.60	6281.92	7884.25
1.595	.....	.....	.....	2688.92	3091.39	3896.34	4701.28	6311.18	7921.07
1.600	.....	.....	....	2701 17	3105.54	3914.27	4723.00	6340.47	7957.94
1.605	.....	.....	.....	2713.43	3119.70	3932.23	4744.75	6369.81	7994.86
1.610	.....	.....	.....	2725 72	3133.88	3950.21	4766.54	6399.19	8031.84
1 615	.....	.....	.....	2738.01	3148.08	3968.21	4788.34	6428.61	8068.88
1.620	.....	.....	.....	2750.33	3162.30	3986.24	4810.19	6458.08	8105.97
1.625	.....	.....	.....	2762.66	3176.54	4004.30	4832.06	6487.58	8143.11
1.630	.....	.....	.....	2775.00	3190.79	4022.38	4853.97	6517.13	8180.31
1.635	.....	.....	.....	2787.36	3205.07	4040.48	4875.90	6546.73	8217.56
1.640	.....	.....	.....	2799.74	3219.36	4058.61	4897.86	6576.36	8254.86
1.645	.....	.....	.....	2812.13	3233.67	4076.76	4919.86	6606.04	8292.22
1.650	.... .	....	.....	2824.54	3248.01	4094.94	4941.88	6635.75	8329.63
1.655	.....	.....	.....	2836.96	3262.35	4113.15	4963.94	6665.51	8367.10
1.660	.....	.....	.....	2849.40	3276.72	4131.37	4986.02	6695.32	8404.62
1.665	.....	.....	.....	2861.85	3291.11	4149.62	5008.13	6725.16	8442.19
1.670	.....	.....	.....	2874.32	3305.51	4167.90	5030.28	6755.04	8479.81
1.675	.....	.....	.....	2886.81	3319.94	4186.20	5052.45	6784.97	8517.49

D'pth on Wier	LENGTH OF THE WIER.								
Ft.	3 Ft.	4 Ft.	6 Ft.	7 Ft.	8 Ft.	10 Ft.	12 Ft.	16 Ft.	20 Ft.
1.680	.....	.....	.....	2899.31	3334.38	4204.52	5074.66	6814.94	8555.22
1.685	.....	.....	.....	2911.82	3348.84	4222.87	5096.89	6844.95	8593.01
1.690	.....	.....	.....	2924.36	3363.32	4241.24	5119.16	6875.00	8630.84
1.695	.....	.....	.....	2936.90	3377.81	4259.63	5141.45	6905.09	8668.73
1.700	.....	.....	.....	2949.46	3392.33	4278 05	5163.78	6935.22	8706.67
1.705	.....	.....	.....	2962.04	3406.86	4296.50	5186.13	6965.40	8744.67
1 710	.....	.....	.....	2974.63	3421.41	4314.96	5208.51	6995.61	8782.72
1.715	.....	.....	.....	2987.24	3435.98	4333.45	5230.94	7025.87	8820 82
1.720	.....	.....	.....	2999 86	3450.56	4351.96	5253.36	7056.17	8858.97
1.725	.....	.....	.....	3012.50	3465.17	4 70.50	5275.84	7086.51	8897.17
1.730	.....	.....	.....	3025.15	3479.79	4389.06	5298.34	7116 88	8935.43
1.735	.....	.....	.....	3037.82	3494.43	4407.65	5320.87	7147.30	8973.74
1.740	.....	.....	.....	3050.50	3509.09	4426.26	5343.43	7177.76	9012 10
1.745	.....	.....	.....	3063.20	3523.76	4444.89	5366.01	7208.26	9050.51
1.750	.....	.....	.....	3075.91	3538.46	4463.55	5388.63	7238.80	9088.98
1.755	.....	.....	.....	3088.64	3553.17	4482.22	5411.28	7269.38	9127.50
1.760	.....	.....	.....	3101.38	3567.90	4500.92	5433.95	7300.01	9166.06
1.765	.....	.....	.....	3114.14	3582.64	4519.65	5456.66	7330.67	9204.68
1.770	.....	.....	.....	3126.91	3597.41	4538 46	5479.39	7361.37	9243.35
1.775	.....	.....	.....	3139.70	3612.19	4557.17	5502.15	7392.11	9282.07
1.780	.....	.....	.....	3152.50	3626.99	4575.97	5524.94	7422.90	9320.85
1.785	.....	.....	.....	3165.32	3641.80	4594.78	5547.76	7453.71	9359.67
1.790	.....	.....	.....	3178.15	3656.64	4613.62	5570.61	7484.58	9398.55
1.795	.....	.....	.....	3190.99	3671.49	4632.49	5593.48	7515.48	9437.47
1.800	.....	.....	.....	3203.85	3686.36	4651.37	5616.39	7546.42	9476.45
1.805	.....	.....	.....	3216.73	3701.24	4670.28	5639.32	7577.40	9515.48
1.810	.....	.....	.....	3229.61	3716.15	4689.22	5662.29	7608.42	9554.56
1.815	.....	.....	.....	3242.52	3731.07	4708.17	5685.27	7639.48	9593.69
1.820	.....	.....	.....	3255.43	3746.01	4727.15	5708.29	7670.58	9632.87
1.825	.....	.....	.....	3268.37	3760.96	4746.15	5731.34	7701.72	9672.10
1.830	.....	.....	.....	3281.31	3775.93	4765.17	5754.42	7732.90	9711.38
1.835	.....	.....	.....	3294.27	3790.92	4784.22	5777.52	7764.11	9750.71
1.840	.....	.....	.....	3307.25	3805.93	4803.29	5800.65	7795.37	9790.09
1.845	.....	.....	.....	3320.24	3820.95	4822.38	5823.81	7826.67	9829.53
1.850	.....	.....	.....	3333.24	3835.99	4841.49	5846.99	7858.00	9869.00
1.855	.....	.....	.....	3346.26	3851 05	4830.63	5870.21	7889.37	9908.54
1.860	.....	.....	.....	3359.29	3866.12	4879 79	5893.45	7920.78	9948.12
1.865	.....	.....	.....	3372.34	3881.21	4898.97	5916.73	7952.24	9987.75
1.870	.....	.....	.....	3385.39	3896.32	4918.17	5940.02	7983.73	10027.43
1.875	.....	.....	.....	3398.47	3911.44	4937.40	5963.35	8015.26	10067.16
1.880	.....	.....	.....	3411.55	3926.59	4956.64	5986.70	8046.82	10106.94
1.885	.....	.....	.....	3424 66	3941.75	4975.91	6010.09	8078.43	10146.77
1.890	.....	.....	.....	3437.77	3956.92	4995.21	6033.50	8110.07	10186 65
1.895	.....	.....	.....	3450.90	3972.11	5014.52	6056.93	8141.76	10226.58
1.900	.....	.....	.....	3464.05	3987.32	5033.86	6080.40	8173.48	10266.56
1.905	.....	.....	.....	3477.21	4002.54	5953 22	6103.89	8205.24	10306.59
1.910	.....	.....	.....	3490.38	4017.78	5972.60	6127.41	8237.04	10346.66
1.915	.....	.....	.....	3593.56	4033.04	5992 00	6150.96	8268.87	10386 79
1.920	.....	.....	.....	3516.76	4048.31	5111.42	6174.53	8300.75	10426.96
1.925	.....	.....	.....	3529.97	4063.60	5130.87	6198 13	8332.66	10467.18
1.930	.....	.....	.....	3543.20	4078.91	5150.34	6221.76	8364.61	10507.46
1.935	.....	.....	.....	3556.44	4094.23	5169.83	6245.42	8396.60	10547.78
1.940	.....	.....	.....	3569.69	4109.57	5189.34	6269.10	8428.62	10588.15
1.945	.....	.....	.....	3582.96	4124.93	5208.87	6292.81	8460.69	10628.56
1.950	.....	.....	.....	3596.24	4140.30	5228.42	6316.54	8492.79	10669.03
1.955	.....	.....	.....	3609.54	4155 69	5248.00	6340.31	8524.93	10709.55
1.960	.....	.....	.....	3622.84	4171.09	5267.60	6364.10	8557.11	10750.11
1.965	.....	.....	.....	3636.17	4186.52	5287.22	6387.92	8589 32	10790.72
1.970	.....	.....	.....	3649.50	4201.95	5306.86	6411.76	8621.57	10831.38
1.975	.....	.....	.....	3662.85	4217.40	5326.52	6435.63	8653.86	10872.10

D'pth on Wier.	LENGTH OF THE WIER.								
Ft.	3 Ft	4 F..	6 Ft.	7 Ft.	8 Ft.	10 Ft.	12 Ft.	16 Ft	20 Ft.
1.980	.....	.....	.....	3676.21	4232.88	5346.20	6459.53	8685.19	10912.85
1.985	.....	.....	.....	3689.58	4248.36	5365.91	6483.47	8718.55	10953.65
1.990	.....	.....	.....	3702.97	4263.86	5385.63	6507.41	8750 95	10994.50
1.995	....	.....	.....	3716.37	4279.38	5405.37	6531 28	8783.39	11035.40
2.000	.....	.....	.....	5729.79	4294.91	5425 12	6555 33	88 5.87	11076 35

Table of Inches and Sixteenths Reduced to Decimals of a Foot.

SIXTEENTHS.	0	1	2	3	4	5	6	7	8	9	10	11	SIXTEENTHS.
0/16	.000	.083	.167	.250	.333	.417	.500	.583	.667	.750	.833	.917	0/16
1/16	.005	.089	.172	.255	.339	.422	.505	.589	.672	.755	.839	.922	1/16
2/16	.010	.094	.177	.260	.344	.427	.510	.594	.677	.760	.844	.927	2/16
3/16	.016	.099	.182	.266	.349	.432	.516	.599	.682	.766	.849	.932	3/16
4/16	.021	.104	.187	.271	.354	.437	.521	.604	.687	.771	.854	.937	4/16
5/16	.026	.109	.193	.276	.359	.443	.526	.609	.693	.776	.859	.943	5/16
6/16	.031	.115	.198	.281	.365	.448	.531	.615	.698	.781	.865	.948	6/16
7/16	.036	.120	.203	.286	.370	.453	.536	.620	.703	.786	.870	.953	7/16
8/16	.042	.125	.208	.292	.375	.458	.542	.625	.708	.792	.875	.958	8/16
9/16	.047	.130	.214	.297	.380	.464	.547	.630	.714	.797	.880	.964	9/16
10/16	.052	.135	.219	.302	.385	.469	.552	.635	.719	.802	.885	.969	10/16
11/16	.057	.141	.224	.307	.391	.474	.557	.641	.724	.807	.891	.974	11/16
12/16	.062	.146	.229	.312	.396	.479	.562	.646	.729	.812	.896	.979	12/16
13/16	.068	.151	.234	.318	.401	.484	.568	.651	.734	.818	.901	.984	13/16
14/16	.073	.156	.240	.323	.406	.490	.573	.656	.740	.823	.906	.990	14/16
15/16	.078	.161	.245	.328	.411	.495	.578	.661	.745	.828	.911	.995	15/16

WEIGHT OF A CUBIC FOOT OF PURE WATER AT DIFFERENT TEMPERATURES.

The following table, prepared by J. B. FRANCIS, shows the weight of a cubic foot of pure water for each degree of temperature of Fahrenheit's thermometer from 32 to 86 degrees inclusive.

Degrees.	Weight.	Degrees.	Weight.
32	62.375	59	62.336
33	62.377	60	62.331
34	62.378	61	62.326
35	62.379	62	62.321
36	62.380	63	62.316
37	62.381	64	62.310
38	62.381	65	62.304
39 *(max.)*	62.382	66	62.298
39.38	62.382	67	62.292
40	62.382	68	62.285
41	62.381	69	62.278
42	62.381	70	62.272
43	62.380	71	62.264
44	62.379	72	62.257
45	62.378	73	62.249
46	62.376	74	62.242
47	62.375	75	62.234
48	62.373	76	62.225
49	62.371	77	62.217
50	62.368	78	62.208
51	62.365	79	62.199
52	62.363	80	62.190
53	62.359	81	62.181
54	62.356	82	62.172
55	62.352	83	62.162
56	62.349	84	62.152
57	62.345	85	62.142
58	62.340	86	62.132

Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.	Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.
1	8.02	8.818.	1.0995	158.3285	51	57.27	.1729	.003019	.4347
2	11.34	4.4093	.3888	55.9872	52	57.84	.1695	.002930	.4219
3	13.89	2.9395	.2116	30.4704	53	58.39	.1663	.002848	.4101
4	16.04	2.2046	.1374	19.7856	54	58.93	.1633	.002771	.3990
5	17.92	1.7637	.0984	14.1795	55	59.48	.1603	.002695	.3880
6	19.65	1.4697	.0747	10 7568	56	60 01	.1574	.002622	.3775
7	21.22	1.2598	.0593	8.5392	57	60.56	.1547	.002554	.3677
8	22.68	1.1023	.0486	6.9984	58	61.08	.1520	.002488	.3582
9	24.03	.9798	.0407	5.8608	59	61.61	.1494	.002424	.3490
10	25.36	.8818	.0347	4.9968	60	62.12	.1469	.002364	.3404
11	26 60	.8016	.0301	4.3344	61	62.71	.1445	.002304	.3317
12	27 78	.7348	.0264	3.8016	62	63.15	.1422	.002251	.3241
13	28.92	.6783	.0234	3.3696	63	63.66	.1399	.002197	.3163
14	30.01	.6299	.0209	3 0096	64	64.16	.1377	.002146	.3090
15	31.06	.5879	.0189	2.7216	65	64.66	.1356	.002097	.3019
16	32.68	.5511	.0171	2.4624	66	65.16	.1336	.002050	.2952
17	33.07	.5187	.0156	2.2464	67	65.65	.1316	.002004	.2885
18	34.03	.4899	.0143	2.0592	68	66.14	.1296	.001959	.2820
19	34.96	.4641	.0132	1.9008	69	66.62	.1278	.001918	.2761
20	35.87	.4409	.0122	1.7568	70	67.11	.1259	.001876	.2701
21	36.75	.4199	.0114	1.6416	71	67.58	.1242	.001837	.2645
22	37.61	.4008	.0106	1.5264	72	68.06	.1224	.001798	.2589
23	38.46	.3831	.0099	1.4256	73	68.53	.1208	.001762	.2537
24	39.29	.3671	0093	1.33.2	74	69.00	.1191	.001726	.2485
25	40.10	.3527	.0087	1.2528	75	69.46	.1175	.001691	.2435
26	40.89	.3391	.0082	1.1808	76	69.92	.1160	.001659	.2388
27	41.67	.3256	.0078	1.1232	77	70.38	.1145	.001626	.2341
28	42 44	.3149	.0074	1.0656	78	70.84	.1130	.001595	.2295
29	43.19	.3040	.0070	1.0080	79	71.29	.1116	.001565	.2253
30	43.93	.2939	.0066	.9504	80	71.71	.1102	.001536	.2211
31	44.65	.2844	.00636	.9158	81	72.19	.1088	.001597	.2170
32	45.37	.2755	.00607	.8740	82	72.63	.1075	.001480	.2131
33	46.07	.2672	.00579	.8337	83	73.07	.1062	.001453	.2092
34	46.77	.2593	.00554	.7977	84	73.51	.1049	.001425	.2052
35	47.45	.2519	.00530	.7632	85	73.95	.1037	.001402	.2018
36	48.12	.2449	.00509	.7329	86	74.38	.1025	.001379	.1985
37	48.78	.2383	.00488	.7027	87	74.81	.1013	.001351	.1949
38	49.44	.2320	.00469	.6753	88	75.24	.1002	.001331	.1915
39	50.09	.2261	.00451	.6494	89	75 67	.0990	.001308	.1883
40	50.72	.2201	.00434	.6249	90	76.09	.0979	.001286	.1851
41	51.35	.2150	.00418	.6019	91	76.51	.0969	.001236	.1823
42	51.98	.2099	.00403	.5803	92	76.93	.0958	.001245	.1792
43	52.59	.2050	.00389	.5594	93	77.35	.0948	.001225	.1764
44	53.20	.2004	.00376	.5414	94	77.76	.0938	.001206	.1736
45	53.80	.1959	.00361	.5241	95	78.18	.0928	.001188	.1710
46	54.40	.1917	00352	.5068	96	78.59	.0918	.001168	.1681
47	54.99	.1876	.00341	.4910	97	79.00	.0909	.001150	.1656
48	55.57	.1837	.00330	.4752	98	79.40	.0899	.001132	.1630
49	56.14	.1799	.00320	.4608	99	79.81	.0890	.001115	.1605
50	56.71	.1763	.00310	.4475	100	80.22	.0881	.001098	.1581

Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.	Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.
101	80.64	.0873	.0010s2	.1558	151	98.56	.0584	.0005925	.08532
102	81.01	.0868	.0010C6	.1535	152	98.89	.0580	.0005865	.08445
103	81.40	.0856	.001051	.1513	153	99.21	.0576	.0005805	.08359
104	81.80	.0847	.0010 35	.1490	154	99.54	.0572	.0005746	.08274
105	82.19	.0839	.001020	.1468	155	99.86	.0568	.0005687	.08189
106	82.58	.0831	.001006	.1448	156	100.18	.0565	.0005640	.08121
107	82.97	.0824	.000993	.1429	157	100.50	.0561	.0005582	.08038
108	83.35	.0816	.000979	.1409	158	100.82	.0558	.0005534	.07968
109	83.74	.0809	.000966	.1391	159	101.14	.0554	.0005477	.07886
110	84.12	.0801	.000952	.1370	160	101.46	.0551	.0005430	.07819
111	84.50	.0794	.000939	.1352	161	101 77	.0547	.0005374	.07738
112	84.88	.0787	.000927	.1334	162	102.09	.0544	.0005328	.07672
113	85 26	.0780	.000914	.1316	163	102.40	.0541	.0005283	.07607
114	85.64	.0773	.000902	.1298	164	102.72	.0537	.0005227	.07526
115	86.01	.0766	.000890	.1281	165	103.03	.0534	.0005182	.07462
116	86.39	.0760	.000879	.1265	166	103.34	.0531	.0005138	.07398
117	86.76	.0753	.000867	.1248	167	103.65	.0528	.0005094	.07335
118	87.13	.0747	.000857	.1234	168	103 96	.0521	.0005040	.07257
119	87.50	.0711	.000848	.1221	169	104.27	.0521	.0004996	.07194
120	87.86	.0734	.000835	.1202	170	104.58	.0518	.0004953	.07132
121	88 23	.0728	.000825	.1188	171	104.89	.0515	.0004911	.07071
122	88.59	.0722	.000814	.1172	172	105.19	.0512	.0004867	.07008
123	88.95	.0716	.000804	.1157	173	105.50	.0509	.0004824	.06946
124	89.31	.0711	.000796	1146	174	105 80	.0506	.0004782	.06886
125	89.67	.0705	.000786	.1131	175	106.11	.0503	.0004740	.06825
126	90.03	.0699	.000776	.1117	176	106.41	.0501	.0004708	.06779
127	90.39	.0694	.000767	.1104	177	106.71	.0498	.0004666	.06719
128	90.74	.0688	.000758	.1091	178	107.01	.0495	.0004625	.06660
129	91.10	.0683	.000719	.1078	179	107.31	.0492	.0004581	.06600
130	91.45	.0678	.0007413	.10674	180	107.61	.0489	.0004541	.06513
131	91.80	.0673	.0007331	.10556	181	107.91	.0487	.0004513	.06498
132	92.15	.0668	.0007249	.10438	182	108.21	.0484	.0004472	.06439
133	92.50	.0663	.0007167	.10320	183	108.50	.0481	.0004433	.06383
134	92.85	.0658	.0007086	.10203	184	108.80	.0479	.0004102	.06358
135	93.19	.0653	.0007007	.10090	185	109.10	.0476	.0004362	.06281
136	93.54	.0648	.0006926	.09973	186	109.39	.0474	.0004332	.06238
137	93.88	.0643	.0006849	.09862	187	109.68	.0471	.0004294	.06183
138	94.22	.0639	.0006780	.09763	188	109 98	.0469	.0004261	.06140
139	91 56	.0634	.0006704	.09653	189	110.27	.0466	.0004225	.06084
140	94.90	.0629	.0006626	.09541	190	110.56	.0464	.0004196	.06042
141	95.24	.0625	.0006562	.09449	191	110 85	.0461	.0004158	.05987
142	95.58	.0621	.0006497	.09356	192	111.14	.0459	.0004129	.05945
143	95 91	.0616	.0006422	.09247	193	111 43	.0456	.0004092	.05892
144	96.25	.0612	.0006358	.09155	194	111.72	.0454	.0004063	.05850
145	96.58	.0608	.0006295	.09064	195	112.01	.0452	.0004025	.05810
146	96.92	.0601	.0006231	.08972	196	112.29	.0449	.0003998	.05757
147	97 25	.0599	.0006159	.08878	197	112.58	.0447	.0003970	.05716
148	97.58	.0595	.0006097	.08779	198	112.86	.0445	.0003942	.05676
149	97.91	.0591	.0006036	.08691	199	113.15	.0443	.0003915	.05637
150	98.23	.0587	.0005975	.08604	200	113.43	.0440	.0003879	.05585

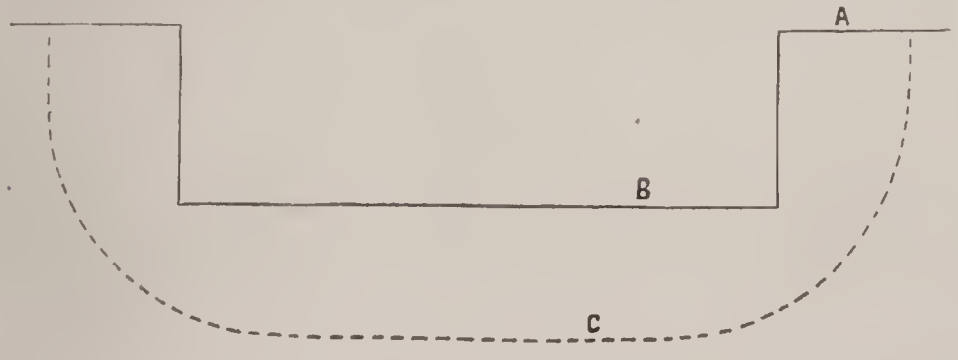
Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.	Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.
201	115.72	.0458	.00038515	.055461	251	127.08	.03513	.00027644	.039807
202	114.00	.0436	.00038245	.055072	252	127.33	.03499	.00027478	.039568
203	114.28	.0434	.00037976	.054685	253	127.58	.03485	.00027316	.039335
204	114.56	.0432	.00037709	.054300	254	127.83	.03471	.00027153	.039100
205	114.84	.0430	.00037443	.053917	255	128.08	.03458	.00026998	.038877
206	115.12	.0428	.00037178	.053535	256	128.33	.03444	.00026837	.038645
207	115.40	.0426	.00036915	.053157	257	128.58	.03431	.00026683	.038423
208	115.68	.0423	.00036656	.052785	258	128.83	.03418	.00026531	.038204
209	115.96	.0421	.00036365	.052279	259	129.08	.03404	.00026371	.037974
210	116.23	.0419	.00036049	.051819	260	129.33	.03391	.00026219	.037755
211	116.51	.0417	.00035790	.051537	261	129.58	.03378	.00026061	.037527
212	116.79	.0415	.00035533	.051167	262	129.83	.03365	.00025918	.037321
213	117.06	.0413	.00035281	.050804	263	130.08	.03353	.00025776	.037117
214	117.34	.0412	.00035111	.050559	264	130.32	.03340	.00025623	.036905
215	117.61	.0410	.00034852	.050186	265	130.57	.03327	.00025480	.036691
216	117.88	.0408	.00034611	.049839	266	130.82	.03315	.00025346	.036489
217	118.15	.0406	.00034363	.049482	267	131.06	.03302	.00025194	.036279
218	118.43	.0404	.00034112	.049121	268	131.31	.03290	.00025055	.036079
219	118.70	.0402	.00033883	.048767	269	131.55	.03278	.00024918	.035881
220	118.97	.0400	.00033621	.048414	270	131.80	.03266	.00024779	.035681
221	119.24	.0399	.00033461	.048183	271	132.04	.03254	.00024644	.035487
222	119.51	.0397	.00033218	.047833	272	132.28	.03242	.00024508	.035291
223	119.78	.0395	.00032977	.047486	273	132.53	.03230	.00024371	.035094
224	120.05	.0393	.00032736	.047139	274	132.77	.03218	.00024237	.034901
225	120.31	.0391	.00032499	.046798	275	133.01	.03206	.00024103	.034708
226	120.58	.0390	.00032343	.046573	276	133.25	.03195	.00023977	.034526
227	120.85	.0388	.00032105	.046231	277	133.49	.03183	.00023822	.034303
228	121.11	.0386	.00031871	.045894	278	133.74	.03172	.00023717	.034152
229	121.38	.0385	.00031710	.045662	279	133.98	.03160	.00023585	.033962
230	121.64	.0383	.00031486	.045339	280	134.22	.03149	.00023461	.033783
231	121.91	.0381	.00031252	.045002	281	134.46	.03138	.00023337	.033605
232	122.17	.0380	.00031104	.044789	282	134.69	.03127	.00023223	.033441
233	122.43	.0378	.00030874	.044458	283	134.93	.03116	.00023093	.033253
234	122.70	.0376	.00030643	.044125	284	135.17	.03105	.00022971	.033078
235	122.96	.0375	.00030497	.043915	285	135.41	.03094	.00022849	.032902
236	123.22	.0373	.00030271	.043590	286	135.65	.03083	.00022727	.032726
237	123.43	.0372	.00030126	.043381	287	135.88	.03072	.00022608	.032555
238	123.74	.0370	.00029901	.043057	288	136.12	.03062	.00022494	.032391
239	124.00	.0368	.00029677	.042734	289	136.36	.03051	.00022374	.032218
240	124.26	.0367	.00029534	.042528	290	136.59	.03040	.00022257	.032050
241	124.52	.0365	.00029312	.042209	291	136.83	.03030	.00022144	.031887
242	124.78	.0364	.00029171	.042006	292	137.06	.03020	.00022034	.031728
243	125.03	.0362	.00028953	.041692	293	137.30	.03009	.00021908	.031547
244	125.29	.0361	.00028813	.041490	294	137.53	.02999	.00021807	.031402
245	125.55	.0359	.00028594	.041175	295	137.76	.02989	.00021697	.031243
246	125.80	.0358	.00028457	.040978	296	138.00	.02979	.00021586	.031083
247	126.06	.0357	.00028319	.040779	297	138.23	.02969	.00021478	.030916
248	126.31	.0355	.00028105	.040471	298	138.46	.02959	.00021370	.030772
249	126.57	.0354	.00027968	.040273	299	138.69	.02949	.00021233	.030618
250	126.82	.0352	.00027811	.040047	300	138.93	.02939	.00021154	.030461

Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.	Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.
301	139.16	.029297	.00021047	.030307	351	150.27	.025124	.00016719	.024075
302	139.39	.029200	.00020948	.030165	352	150.49	.025052	.00016646	.023970
303	139.62	.029104	.00020845	.030016	353	150.70	.024981	.00016570	.023860
304	139.85	.029008	.00020742	.029858	354	150.91	.024911	.00016506	.023768
305	140.08	.028913	.00020640	.029721	355	151.13	.024841	.00016436	.023667
306	140.31	.028819	.00020539	.029576	356	151.34	.024771	.00016367	.023568
307	140.54	.028725	.00020439	.029432	357	151.55	.024702	.00016299	.023470
308	140.77	.028631	.00020338	.029286	358	151.76	.024633	.00016231	.023372
309	141.00	.028539	.00020240	.029145	359	151.98	.024564	.00016162	.023273
310	141.22	.028447	.00020143	.029035	360	152.19	.024496	.00016095	.023176
311	141.45	.028355	.00020046	.028866	361	152.40	.024428	.00016028	.023083
312	141.68	.028264	.00019949	.028726	362	152.61	.024360	.00015962	.022985
313	141.90	.028174	.00019854	.028589	363	152.82	.024293	.00015896	.022890
314	142.13	.028084	.00019759	.028452	364	153.03	.024226	.00015830	.022795
315	142.36	.027995	.00019665	.028317	365	153.24	.024160	.00015766	.022703
316	142.58	.027907	.00019572	.028183	366	153.45	.024094	.00015701	.022609
317	142.81	.027819	.00019479	.028049	367	153.66	.024028	.00015637	.022517
318	143.03	.027731	.00019388	.027918	368	153.87	.023963	.00015573	.022425
319	143.26	.027644	.00019296	.027786	369	154.08	.023898	.00015510	.022334
320	143.48	.027558	.00019206	.027656	370	154.29	.023834	.00015447	.022243
321	143.71	.027472	.00019109	.027516	371	154.49	.023769	.00015385	.022154
322	143.93	.027387	.00019027	.027398	372	154.70	.023705	.00015323	.022065
323	144.15	.027302	.00018939	.027272	373	154.91	.023642	.00015261	.021975
324	144.38	.027217	.00018850	.027144	374	155.12	.023579	.00015200	.021888
325	144.60	.027134	.00018764	.027020	375	155.33	.023516	.00015139	.021800
326	144.82	.027050	.00018678	.026896	376	155.53	.023453	.00015079	.021713
327	145.04	.026968	.00018593	.026773	377	155.74	.023391	.00015019	.021627
328	145.27	.026886	.00018507	.026650	378	155.95	.023329	.00014959	.021540
329	145.49	.026804	.00018423	.026529	379	156.15	.023268	.00014901	.021457
330	145.71	.026723	.00018339	.026408	380	156.36	.023206	.00014841	.021371
331	145.93	.026642	.00018256	.026288	381	156.56	.023145	.00014783	.021287
332	146.15	.026562	.00018174	.026170	382	156.77	.023085	.00014725	.021204
333	146.37	.026482	.00018092	.026052	383	156.97	.023025	.00014668	.021121
334	146.59	.026403	.00018011	.025935	384	157.18	.022965	.00014610	.021038
335	146.81	.026324	.00017931	.025820	385	157.38	.022905	.00014553	.020956
336	147.05	.026245	.00017843	.025693	386	157.59	.022846	.00014497	.020875
337	147.25	.026168	.00017771	.025590	387	157.79	.022787	.00014441	.020795
338	147.46	.026090	.00017692	.025476	388	157.99	.022728	.00014385	.020714
339	147.68	.026013	.00017614	.025364	389	158.20	.022669	.00014329	.020633
340	147.90	.025937	.00017536	.025251	390	158.40	.022611	.00014274	.020554
341	148.12	.025861	.00017459	.025140	391	158.60	.022554	.00014220	.020476
342	148.33	.025781	.00017383	.025032	392	158.81	.022496	.00014165	.020397
343	148.55	.025710	.00017307	.024922	393	159.01	.022439	.00014111	.020319
344	148.77	.025635	.00017231	.024812	394	159.21	.022382	.00014058	.020243
345	148.98	.025561	.00017157	.024706	395	159.41	.022325	.00014004	.020165
346	149.20	.025487	.00017082	.024598	396	159.62	.022269	.00013951	.020089
347	149.41	.025413	.00017008	.024491	397	159.82	.022213	.00013898	.020013
348	149.63	.025340	.00016928	.024376	398	160.02	.022157	.00013846	.019938
349	149.85	.025268	.00016862	.024281	399	160.22	.022101	.00013794	.019863
350	150.06	.025196	.00016790	.024177	400	160.42	.022046	.00013742	.019788

Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.	Head in Feet.	Velocity due Head.	Cubic Feet per Second to one H. P.	Section of Stream in Square Feet to 1 H. P.	Section of Stream in Square Inches to 1 H. P.
401	160.62	.021991	.00013691	.019715	451	170.34	.019553	.00011478	.016528
402	160.82	.021936	.00013640	.019641	452	170.53	.019510	.00011440	.016473
403	161.02	.021882	.00013589	.019568	453	170.72	.019467	.00011402	.016418
404	161.22	.021828	.00013539	.019496	454	170 91	.019424	.00011365	.016365
405	161.42	.021774	.00013489	.019424	455	171.09	.019381	.00011327	.016310
406	161.62	.021720	.00013438	.019356	456	171 28	.019339	.0001129	016257
407	161.82	.021667	.00013389	.019280	457	171.47	.019296	.00011253	.016204
408	162.02	.021614	.00013340	.019209	458	171.66	.019254	.00011216	.016151
409	162.21	.021561	.00013291	.019139	459	171.84	.019212	.00011180	.016099
410	162.41	.021508	.00013243	.019069	460	172.03	.019170	.00011143	.016045
411	162.61	.021456	.00013194	.018999	461	172 22	.019129	.00011107	.015994
412	162.81	.021404	.00013146	.018930	462	172.40	.019087	.00011071	.015942
413	163.01	.021352	.00013098	.018861	463	172.59	.019046	.00011035	.015890
414	163.20	.021301	.00013052	.018794	464	172.78	.019005	.00010999	.015838
415	163.40	.021249	.00013004	.018725	465	172.96	.018964	.00010964	.015788
416	163.60	.021198	.00012957	.018658	466	173.15	.018924	.00010929	.015737
417	163.79	.021147	.00012911	.018591	467	173.34	.018883	.00010893	.015685
418	163.99	.021097	.00012864	.018524	468	173.52	.018843	.00010858	.015636
419	164.19	.021046	.00012818	.018457	469	173.71	.018803	.00010824	.015586
420	164.38	.020996	.00012772	.018391	470	173.89	.018763	.00010790	.015537
421	164.58	.020946	.00012726	.018325	471	174 08	.018723	.00010755	.015487
422	164.77	.020897	.00012682	.018262	472	174.26	.018683	.00010721	.015438
423	164.97	.020847	00012633	.018195	473	174.45	.018644	.00010687	.015389
424	165.16	.020798	.00012592	.018132	474	174.63	.018604	.00010653	.015310
425	165.36	.020749	.00012547	.018967	475	174.81	.018565	.00010620	.015292
426	165.55	.020700	.00012503	.018004	476	175.00	.018526	.00010585	.015243
427	165.75	.020652	.00012459	.017940	477	175.18	.018487	.00010553	.015196
428	165.94	.020604	.00012416	.017879	478	175.36	.018449	.0001 520	.015148
429	166.13	.020556	.00012373	.017817	479	175.55	.018410	.00010487	.015101
430	166.33	.020508	.00012329	.017753	480	175.73	.018372	.00010454	.015053
431	166.52	.020460	.00012286	.017691	481	175.91	.018333	.00010421	.015006
432	166.71	.020413	.00012244	.017631	482	176.10	.018295	.00010388	.014958
433	166.91	.020366	.00012201	.017569	483	176.28	.018258	.00010357	.014914
434	167.10	.020319	.00012158	.017508	484	176.46	.018220	.00010325	.014868
435	167.29	.020272	.00012117	.017448	485	176.64	.018182	.00010293	.014821
436	167.48	.020226	.00012076	.017389	486	176.83	.018145	.00010261	.014775
437	167.67	.020179	.00012034	.017328	487	177.01	.018108	.00010229	.014729
438	167.87	.020133	.00011993	017269	488	177.19	.018070	.00010198	.014685
439	168.06	.020087	.00011952	.017210	489	177.37	.018033	.00010166	.014639
440	168.25	.020042	.00011912	.017153	490	177.55	.017996	.00010135	.014594
441	168.44	.019996	.00011871	.017094	491	177 73	.017960	.00010105	.014551
442	168.63	.019951	.00011831	.017036	492	177.91	.017924	00010074	.014506
443	168.82	.019906	.00011791	016979	493	178.10	.017887	.00010043	.014461
444	169.01	.019831	.00011751	.016921	494	178.28	.017851	.00010012	.014417
445	169.20	.019817	.00011712	.016865	495	178 46	.017815	.00009982	.014374
446	169.39	.019772	.00011672	.016807	496	178.64	.017779	.00009952	.014330
447	169.58	.019728	.00011633	.016751	497	178.82	.017743	00009922	.014287
448	169.77	.019684	.00011594	.016695	498	179.00	.017708	.00009892	.014244
449	169.96	.019640	.00011555	016639	499	179.18	.017672	.00009862	.014201
450	170 15	.019596	.00011515	.016583	500	179.35	.017637	.000 9833	.014159

MEASUREMENT OF WATER.

It seems to be generally conceded by those conversant with the subject, that the most accurate method practicable for determining the quantity of water running in any stream, is to measure it while it is flowing over a weir constructed like the diagram below. The dotted line C represents the bed of the stream. Lines A and B represent the top of the dam or weir; the opening B must be of sufficient length to allow the water to pass between the vertical ends below the line A. The crest of the weir B must be of sufficient hight to cause a fall equal at least to one-half of the depth of water running over it. The crest of the weir and the vertical ends must be beveled back at an angle of 45 degrees on the down stream side, that a sharp corner may be presented to the stream as it passes through. Up stream, five or six feet from the weir, a stake should be placed at the edge of the water and a mark made on it level with the crest of the weir, and the water should be measured from that mark instead of at the weir. The reliability of the results depend upon the accuracy of the measurement.



But where a weir cannot be used, if the water flows through a canal or race of uniform rectangular section, or if a place can be found in the stream of fifty feet or more in length, that is nearly straight and of uniform section, the quantity may be ascertained by multiplying the area of the cross-section by the average velocity.

The area of the cross-section is the width of the stream multiplied by the average depth. The average velocity is ascertained in the following manner: Select a portion of the stream that is as nearly straight as may be, and where the current seems to be uniform for fifty feet or more, and mark the distance upon the bank in a convenient manner; then go fifteen or twenty feet above the upper mark and put a small float (a light chip will answer, but a small body that will float nearly submerged is better, as it will not be affected by wind) in the centre of the current so that it will acquire the velocity of the current before it reaches the first mark; then note the time required for the float to pass from one mark to the other, and this operation repeated a number of times to insure against error will give nearly the *surface* velocity; the *average* velocity is generally taken as four-fifths of the surface velocity.

The area of cross-section taken in square feet multiplied by the average velocity taken in feet per minute will give the cubic feet flowing per minute. This method is very convenient but not very reliable unless great care is exercised throughout.

SCROLL WHEELS.

It is generally understood that Scroll wheels decrease in useful effect as they increase in size, but to what extent has never been determined. The point is one of considerable importance, for such wheels are generally simple in construction, not very liable to get out of order, and can be set up at small expense.

The rapid deterioration of iron wheels, is a subject deserving more consideration than it has received. Much has been done to determine the comparative value of new wheels, while nothing has been done to ascertain whether the wheel that gives the best result when new, continues to do so after running a year.

During the experiments with the Cook Wheel, the entire set of buckets were changed three times, each change occupying about an hour's time. This was done to demonstrate the facility with which such changes could be made in case of accident, or for the purpose of cleaning and painting the wheel to prevent deterioration.

In another part of this work, allusion is made to the want of more economical wheels at part gate; until that want is supplied, it would seem to be policy for manufacturers to use several wheels,—one or more, good at whole gate,—to be run at their full capacity; then a smaller one, comparatively good at part gate, to be used to regulate with.

EMERSON'S LEVER DYNAMOMETER

FOR SHAFTING.

As I am constantly receiving applications for Dynamometers for weighing the power required to drive mills and machinery, I herewith publish cuts and descriptions of the different kinds, with other information, likely to be of general interest. As inventor of the method, and having expended much time and thought in perfecting the different plans illustrated, I am, of course, desirous to have them become generally useful, though, as stated in the introduction to this work, I have no pecuniary interest in them. Any person of ordinary intelligence can see that they are constructed upon the same principle as the Fairbanks' Platform Scales, and may be made as reliable. Some of the following articles were copied from circulars, while others were furnished by parties of experience for the benefit of those using the same kind of machinery. In my next edition of this work, I intend to publish a great variety of experiments soon to be made by Government Engineers, also by Prof. R. H. Thurston, C. E., of the Stevens Institute.

From the London Engineering.

"A thoroughly reliable Dynamometer of simple construction, and capable of being readily applied, is an instrument which might be employed with advantage in a

vast number of cases. Almost all employers of machinery are interested in the amount of power which their machines require to drive them, and the accurate measurement of this power would, in a vast number of instances, lead to the discovery of sources of waste which at present pass unnoticed. In other cases, also, where mechanical power is hired, it is of importance both to the hirer and letter, that the power thus supplied should be determined accurately. Altogether there is a great want of a simple and reliable Dynamometer, and for this reason we illustrate an instrument of this kind which has been lately introduced in the United States, and of the performance of which good accounts are given. This Dynamometer has been designed by Mr. James Emerson. Referring to the engraving, it will be seen that all the motions are absolute. There is no dependence upon springs, spiral, or other forms, which are so liable to be affected by changes of temperature, and so unreliable under variations of power.

"It is very simple in construction, and direct in operation. The pulley A is loose on the shaft, and receives the power. Its connection with the shaft is made by means of a wheel (the spider J) keyed or screwed firmly to the shaft in close contiguity with the receiving pulley, its hub, in fact, forming one of the guides to the position of the pulley on the shaft. To connect this fixed wheel with the loose receiving pulley, a bell crank lever is pivoted into projecting ears on the rim of the wheel on opposite sides, the long arm of which connects with an annular slotted collar on the shaft by means of the short bars B. The short arms of the bell crank levers connect on the inside of the fixed wheel with two radial bars, one parallel to the outer arm of the bell crank, and the other at right angles to it, receiving near its upper end a pivot

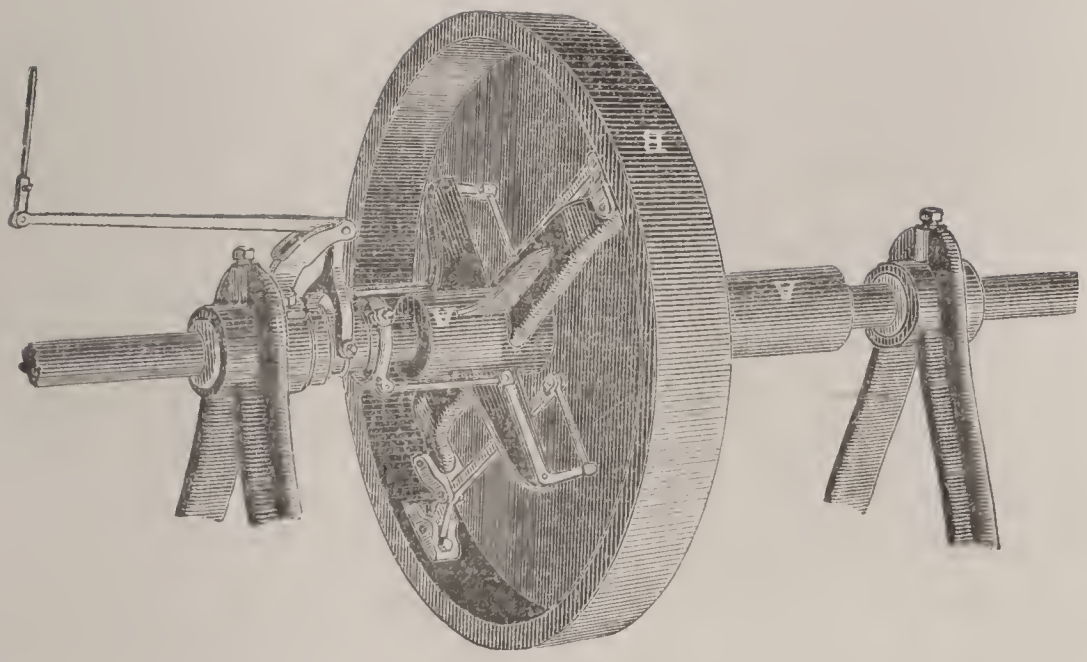
EMERSON'S LEVER DYNAMOMETER FOR SHAFTING.

passing through a swivel hung to the rim of the wheel, and having its extreme end pivoted to a stud fixed on the inner side of the rim of the receiving pulley. It will be seen from this description that the strain of the power received through the belt on A, will necessarily re-act on the levers, and, through them, on the fixed wheel, which may be considered nothing more nor less than a support to these levers in sustaining them in position to connect the loose receiving pulley with the shaft.

"At B, it will be seen, the levers are connected by pivots with the sliding collar, in the annular groove of which is seated a strap with which is connected a forked lever, the fulcrum at C. To the end of the long arm of this lever a rod with a short section of machine chain is attached. This chain runs over the cylindrical head D of a pendulum weight E, having a pointer that traverses a fixed quadrant F, properly divided by a scale to denote the relative pressure exerted through the medium of the receiving pulley on the shaft. The pulley G is fixed to the shaft, and delivers the power.

"With this description of the parts, and an examination of the engraving, any of our readers may understand the operation of the device. It will be seen that all the motions are absolute. It is a weighing machine as correct in principle as the old-fashioned steelyards or the platform scales; in fact, it is simply a rotary platform scale, and each machine is weighed and tested in place by hanging to the pulley A, sealed weights, and marking the index as each weight is added."

An instrument like the one described, of two hundred and fifty horse-power, has been in use on the main shaft of the Wamesit Power Co.'s works, at Lowell, Mass., for four years, and seemingly is as perfect as the day it was put on.



DYNAMOMETER APPLIED AT COUPLING OF SHAFT.

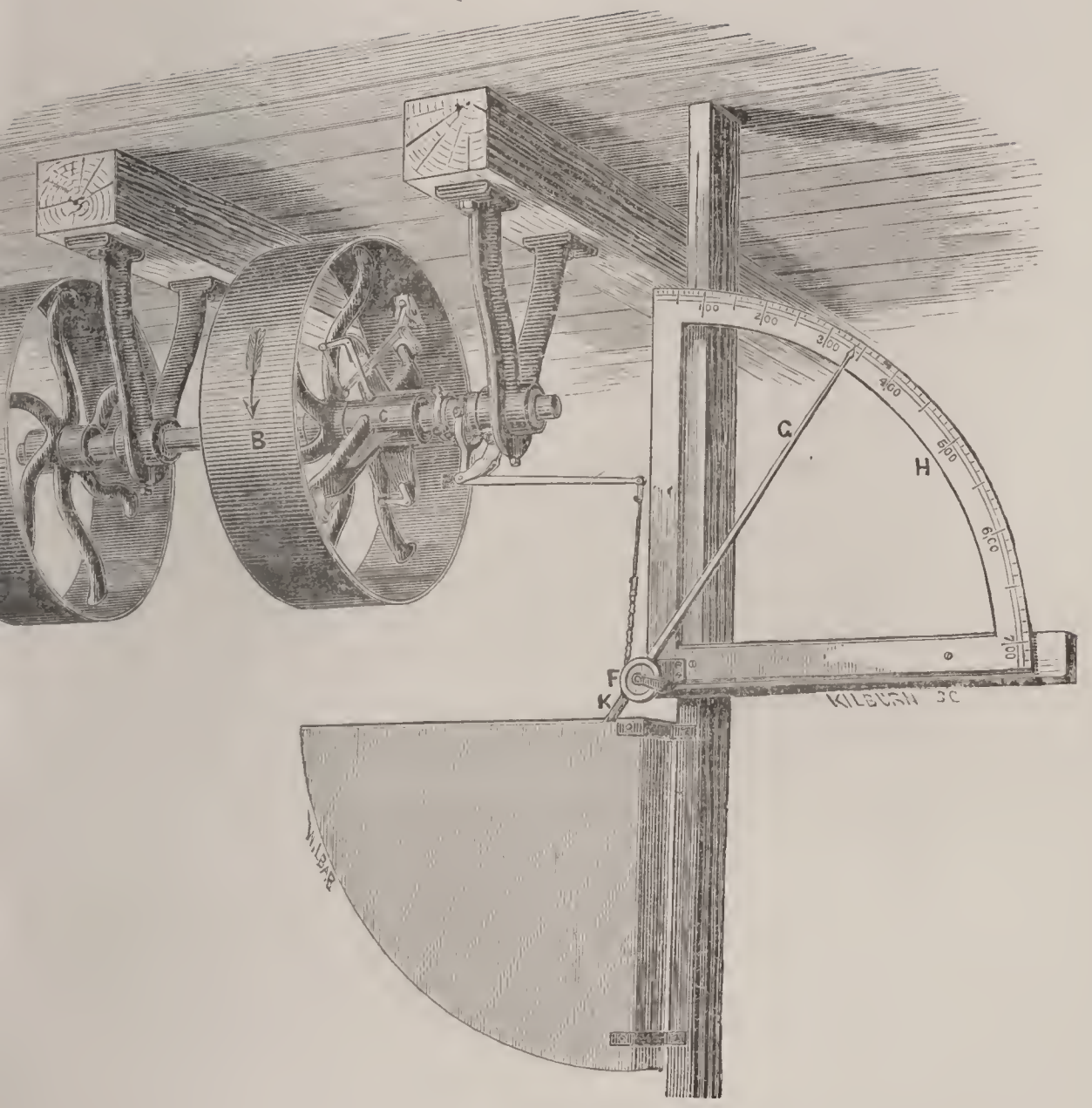
DYNAMOMETER APPLIED AT COUPLING OF SHAFT.

The engraving on preceding page represents a Dynamometer of 600 horse-power on the main shaft of the Lawrence Duck Co.'s Mill at Lawrence, Mass., Isaac Hayden, Agent. It is placed at a joint in the shaft, the coupling having been removed. The arrangement is very simple, and takes but little more room than the couplings did.

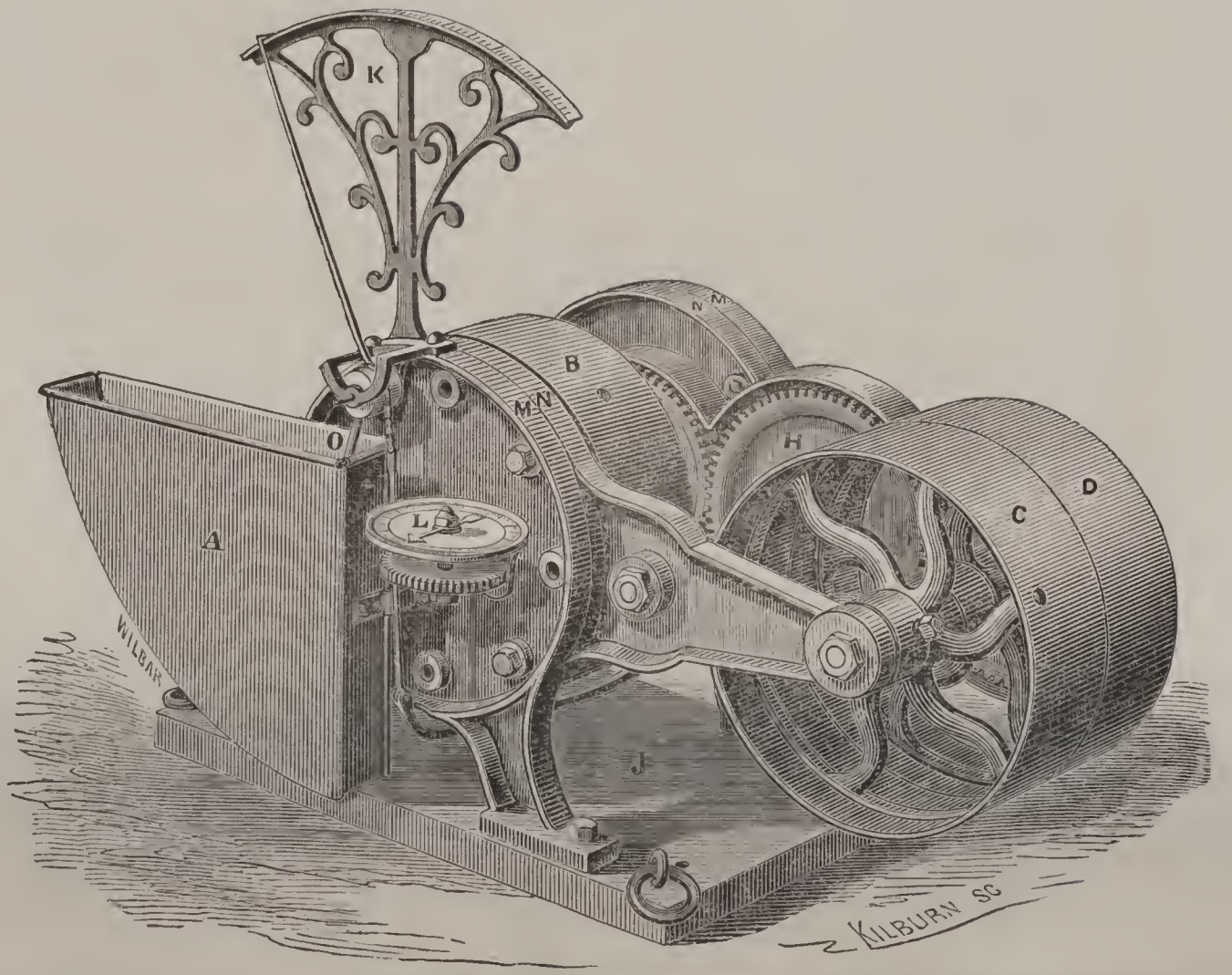
In one instance where an instrument, similar in construction, was placed upon a shaft, it was found that sixteen horse-power was used instead of four, as was supposed. In another instance so much difference was found, that the difference in rent each month equalled the cost of the Dynamometer. Of the power used in a mill 25 per cent. is generally required to drive shafting.

PORTABLE OR STATIONARY.

The engraving on opposite page represents one that can be used as a stationary or portable instrument, as it can be changed from place to place, suspended from ceiling, or inverted and placed on floor, or it can be attached to the end of a shaft, using pulley B as driving pulley, and was selected in preference to either of the others, by Franklin A. Stratton, Engineer, at Washington Navy Yard, for the Government service. I should generally select it as a portable instrument for testing anything except the lightest kind of machinery. The weighing arm on all kinds is now generally immersed in water to keep it steady.



PORTABLE OR STATIONARY.



PORTABLE DYNAMOMETERS.

PORTABLE DYNAMOMETERS.

Made of different sizes, for testing Pickers, Looms, Spinning Frames, or any kind of machinery, by being placed between machine and motor, connected by belts on its pulleys and weighing the power in transmission through it. May be used where power is rented, but the stationary kind is far the best for that purpose. A tenant can always favor his power where the Dynamometer is applied temporarily. One of this kind has been purchased for general experimental purposes at the Stevens Institute, Hoboken, New Jersey.

All of the Dynamometers are graduated by applying the weights at a point which, if revolving, would describe a circle of a given number of feet, the smallest size now sold generally at 4, the larger from 10 to 60 depending somewhat upon the speed they are to run.

The same method is used to compute the power as described in water-wheel tests. Suppose the instrument to be graduated upon a 4-foot circle, pulley making 500 revolutions per minute, weight indicated after deducting, centrifugal force, 35 pounds. $500 \times 4 = 2000 \times 35 = 70{,}000 \div 33{,}000 = 2.12$ H. P.

The manner of using the Portable Dynamometer is to place it between the motor and machine to be tested, level and secure it to the floor, then belt from motor to driving pulley of Dynamometer, and observe the weight indicated, caused by centrifugal force of the levers (equivalent to balancing scales), then belt from pulley of Dy-

namometer to pulley of machine, from the weight then indicated, deduct the centrifugal force, then compute as before described.

Recently, I was employed to test the power used by a tenant who was paying three hundred dollars per year. It was supposed he was using about two horse-power. My Dynamometer had twenty-four inch pulleys with six inch face; the tenant was using a six inch belt on thirty-six inch pulleys, and could only run a part of his machinery at a time. A single six inch belt on the twenty-four inch pulleys, when strained very tight, would lift three hundred pounds, but would not run the machinery required. A double belt of the same width, cut four inches short, in a length of twenty feet, was then tried and found capable of running all that the single belt over the thirty-six inch pulleys would run; then all of the belts (except one to drive a picker) were thrown off, and the belt on the Dynamometer was run at a speed of nine hundred and ten feet per minute, the indicator showing a weight of four hundred and fifty pounds; and this before any cotton was fed in. After running a few minutes, the Picker was supplied with cotton. In a moment the teeth of the gears H, on the Dynamometer, were shaved off as though they had been made of wood. The gears were thirteen and a half inches in diameter, two inch face. Upon examination of the Picker, it was found that its gears were completely choked with waste and dirt; and from my experience in the past four years, testing power, I believe that in many cases about as much power is wasted by neglect and bad management, as is really required to do the necessary work. I am often met with the statement, "O, I know just what power it takes to run my machines; *that* was settled in England long ago." Perhaps it was there, but the Dynamometer often unsettles it here. I have found

two Half Frames, seemingly exactly alike in every particular, yet one required thirty-one thousand foot pounds to drive it, while the other required less than twenty-three thousand.

Engines have been found that used abundance of fuel without giving out much power. In one case, where an engine was used that worked the steam twice, first in a six inch cylinder, then in a twelve, using over a cord of wood per day, the proprietor was positive that he was furnishing twenty horse power, but the Dynamometer would only show seven. Then it was found that the friction of the working parts of the engine was so great that but a comparatively small part of the power was transmitted.

The difference between the supposed and actual power used is not always one way, but a difference is frequently found sufficient to pay for a Dynamometer in a short time, but the greatest value that would arise from its general use would result from its tendency to produce more economy in the use of power.

EXPERIMENTS FURNISHED BY VARIOUS PARTIES.

LOWELL, March 8th, 1872.

James Emerson:

DEAR SIR,—I send, according to your request, a copy of some reports of tests, made by me with your Dynamometer.

Respectfully yours,

CHANNING WHITAKER.

Report of a test to determine the power required to run one of the Rag Engines at Bacon's Paper Mill, in North Lawrence, Massachusetts.

LOWELL, December 16th, 1870.

J. A. Bacon, Esq.

DEAR SIR,—I have worked up carefully the tests made yesterday with Emerson's Dynamometer, at your mill in North Lawrence.

When the engine roll made 145 revolutions per minute, the dial hand of the Dynamometer made 3.8 revolutions per minute.

I have estimated the speed of the roll, upon the supposition that it varied during the different tests in the same proportion as the speed of the dial hand.

I give the results obtained, in the order in which the tests were made.

Number of Test.	CONDITION OF THE ENGINE.	Revolutions of Roll per minute.	Horse-Power indicated by Dynamometer.
1	No paper in.....	137	2.5
2	Paper being put in..	149	7.26
3	" " " " ..	141	3.36
4	Washing paper.....	153	4.
5	" "	145	4.03
6	" "	147	4.41
7	" "	144	4.57
8	" "	145	5.19
9	" "	153	5.2
10	" "	148	4.71
11	Beating pulp.....	149	5.08
12	" "	147	5.02
13	" "	149	5.08
14	Brushing the paper..	149	3.9

While the paper was being put in, the power indicated gradually rose from 2.5 horse-power to 7.26 horse-power. It stood at 7.26 horse-power for about three minutes, after which it gradually fell to 3.36 horse-power.

From test 4 to test 8, the roll was gradually set down harder and harder. At test No. 7, the roll was down as hard as is usual in making paper. At test No. 8, the roll was down harder than is common.

Very respectfully yours,

(Signed,) CHANNING WHITAKER,

Mechanical Engineer.

Report of a test to determine the power required to drive Shoemaking Machinery, at the State Prison, in Charlestown, Massachusetts.

LOWELL, July 13th, 1871.

Rodney S. Tay, Esq., Treasurer Tucker Manfg. Co., Boston.

MY DEAR SIR,—On the 13th inst., I made a test with Emerson's Small Dynamometer, of the power required to drive Mr. Blanchard's Shoemaking Machinery at the State Prison, in Charlestown.

L of C

In Mr. Blanchard's lower room there are, besides the Counter-Shafting, 12 sewing machines, 2 peggers, 2 skivers, 1 heel trimmer, 1 bottom roller, 1 buffer, 1 roller, 1 splitter.

All of the machinery is not in use at any one time. But making such allowance for this fact as seems to be fair, there is required for driving the machinery and counter-shafting in this room, 4.9 horse-power.

In Mr. Blanchard's upper room, there are, besides the counter-shafting, 2 brushes and 4 buffers.

There is required, for driving the machinery and counter-shafting in this room, 2.3 horse-power.

Making a total of 7.2 horse-power used by Mr. Blanchard.

Very respectfully yours,

(Signed,) CHANNING WHITAKER,
Mechanical Engineer.

P. S.—A Beating Engine, of usual size and construction, for converting tarred hemp rope (old junk) into paper, requires, when running at two hundred revolutions per minute, from five to twenty-five horse-power, varying according to the amount of stock in the vat, and also according to the stage of the operation.

C. W.

EXPERIMENTS AT MASSACHUSETTS COTTON MILLS.

LOWELL, MASS., MARCH, 1872.

Trial of power required to drive 15 stretchers, (3d speeders) 52 spindles each = 780 spindles. Speed main shaft of machine, 396 revolutions. Speed of flier, 1121 revolutions. Frames driven by a train of 8 counter-shafts—two frames by each, except the last, which drives one. These shafts are driven, the first from the main line, and the others in succession from each other.

1st. Machines and shafting required 8056 lbs. per sec. = 14.65 horse-power = 537 lbs. or .976 horse-power each = 10.3 lbs. per spindle = 53.24 spindles per horse-power.

2d. Shafting and loose pulleys, 2000 lbs. = 3.64 horse-power.

3d. Shafting alone, belts off, 732 lbs. = 1.33 horse-power.

Trial of power to drive 6 throstle spinning frames (warp), 5 having 128 spindles each, and one 112 spindles, = 752 spindles, driven by a train of 6 counter-shafts, the first belted from the main line, and the others in succession from each other. This being an odd row of frames, only one frame is belted from each shaft. Spinning No. 20 yarn, cylinder running 750 revolutions, and fliers 4312 revolutions, per minute.

1st. Shafting and loose pulleys, 1150 lbs. = 2.09 horse-power.

2d. Shafting alone, machine belts off, 767 lbs. = 1.39 horse-power.

3d. Frames and shafting, 6900 lbs. = 12.54 horse-power.

Trial of power required for 112 looms, weaving 36 inch sheetings, No. 20 yarn, 60 threads to the inch each, warp and filling. Speed, 130 picks per minute. These looms are placed in the back part of the middle portion of No. 1 mill—one-half in the basement and half in the room above—being belted from 5 lines of shafting in the lower room. These shafts are driven in succession, one from the other, the first from the main line. Size of Shafting, 2 3-16 in., except the first piece in each line, on which the counter-pulleys are placed; these are of several different sizes, but about 2½ inch on an average. The driving pulleys are 12 inch diameter, and the loom pulleys 14 inch.

1st. 112 looms with shafting lubricated with tallow. Average of several trials: 8870 lbs. = 16.13 horse-power = 79.20 lbs. per loom = 7.24 looms per horse-power.

2d. The same, after oiling the journals of the shafting: 8492 lbs. = 15.44 horse-power = 75.82 lbs. per loom = 7.24 looms per horse-power.

3d. Trial of shafting and loose pulleys, lubricated with tallow. Average of several trials: 2876 lbs. = 5.23 horse-power.

4th. Same after freshly oiling: 2245 lbs. = 4.08 horse-power.

5th. Shafting alone, belts off: 913 lbs. = 2.40 horse-power.

Trial of power required to drive 8 Lowell Machine Shop Mules, 624 spindles each, with Emerson's Dynamometer. Five mules were running on No. 22 yarn, spindles making 5500 revolutions per minute, and three mules on No. 37 yarn, spindles making 6230 revolutions per minute.

1st. The 8 mules, including shafting.

12250 lbs. = 22.25 horse-power, = 2.45 lbs. per spindle, = 224 spindles per horse-power.

2nd. Shafting alone, 17.10 lbs. = 3.11 horse-power, = 14 per cent. of the whole power.

3rd. 8 mules without shafting, 19.16 horse-power = 211 lbs. per spindle = 260 spindles per horse-power.

THE SAWYER RING SPINNING MACHINE.

A new spinning machine for cotton, known as the Sawyer Ring Spinning Frame, has recently been extensively introduced in New England.

The new machine differs from those heretofore used, principally in the construction of the spindles and their bearings; the spindle being made of about one fourth the usual weight, while its bearings are so arranged, as to ensure less vibration of the spindle while running at a speed from twenty to twenty-five per cent. greater than that at which the old form will run satisfactorily.

It will be seen by the following table of experiments made at the Ashton Mill, (Lonsdale, R. I.), that seventy-five per cent. more work can be done, in the same time, with a horse-power, on the improved than on the old machine; and as somewhat more than half the power of cotton mills has heretofore been consumed in spinning, the importance of this improvement to manufacturers is evident.

It is further claimed, that the advantages resulting from the increased production per spindle, requiring less original outlay for machines to do a given amount of work, less room in the mill for the machines, and less expense for labor, are fully equal to those resulting from the saving in power.

EXPERIMENTS ON RING SPINNING MACHINES, AT ASHTON MILLS, 1871.

	Common Ring Frame.	Sawyer's Ring Frame.
Number of spindles in a frame	160	160
Revolutions of spindles per minute	5893	7003
Ratio of speed of spindles	100	$118\frac{8}{10}$
Speed of front rolls	58	$72\frac{1}{2}$
Horse-powers per frame	1.49	1.00
Pounds feet per second per spindle	5.14	3.44
Number of spindles driven by one horse-power	$107\frac{1}{2}$	160
Relative work done by one horse-power	100	$176\frac{8}{10}$
Number of yarn spun	50	42

LANCASTER MILLS, CLINTON, MASS., }
September 11th, 1871. }

J. H. Sawyer, Esq.:

DEAR SIR: Three weeks ago Mr. Draper fitted one of our spinning frames with your new spindle, and on Saturday last I tested the power required to drive the same; as it is somewhat less than you had stated, I thought you might perhaps be interested in the following memorandum.

Frame built by Fales, Jenks & Sons, about 1½ years ago, and fitted with "Sawyer" spindle three weeks ago; No. of yarn, 25 warp; revolutions of front roll, 96; revolutions of spindle, 6645: bobbins full (bobbins weighed 10 lbs., yarn on same weighed 17 lbs.; No. of spindles, 208; power consumed, 1.598 horse-power, = 4.208 lbs. per spindle.

Doffed the frame, put on fresh bobbins, and found power consumed to be 1.3 horse-power, = 3.437 lbs. per spindle, giving average for half full bobbin 3.822 lbs. per ft. per sec. per spindle.*

In the first experiment the bobbins were much fuller than usual, they completely filled the ring and weighed about 2 lbs. more than the average doff.

Yours truly,

GEORGE W. WEEKS, Superintendent.

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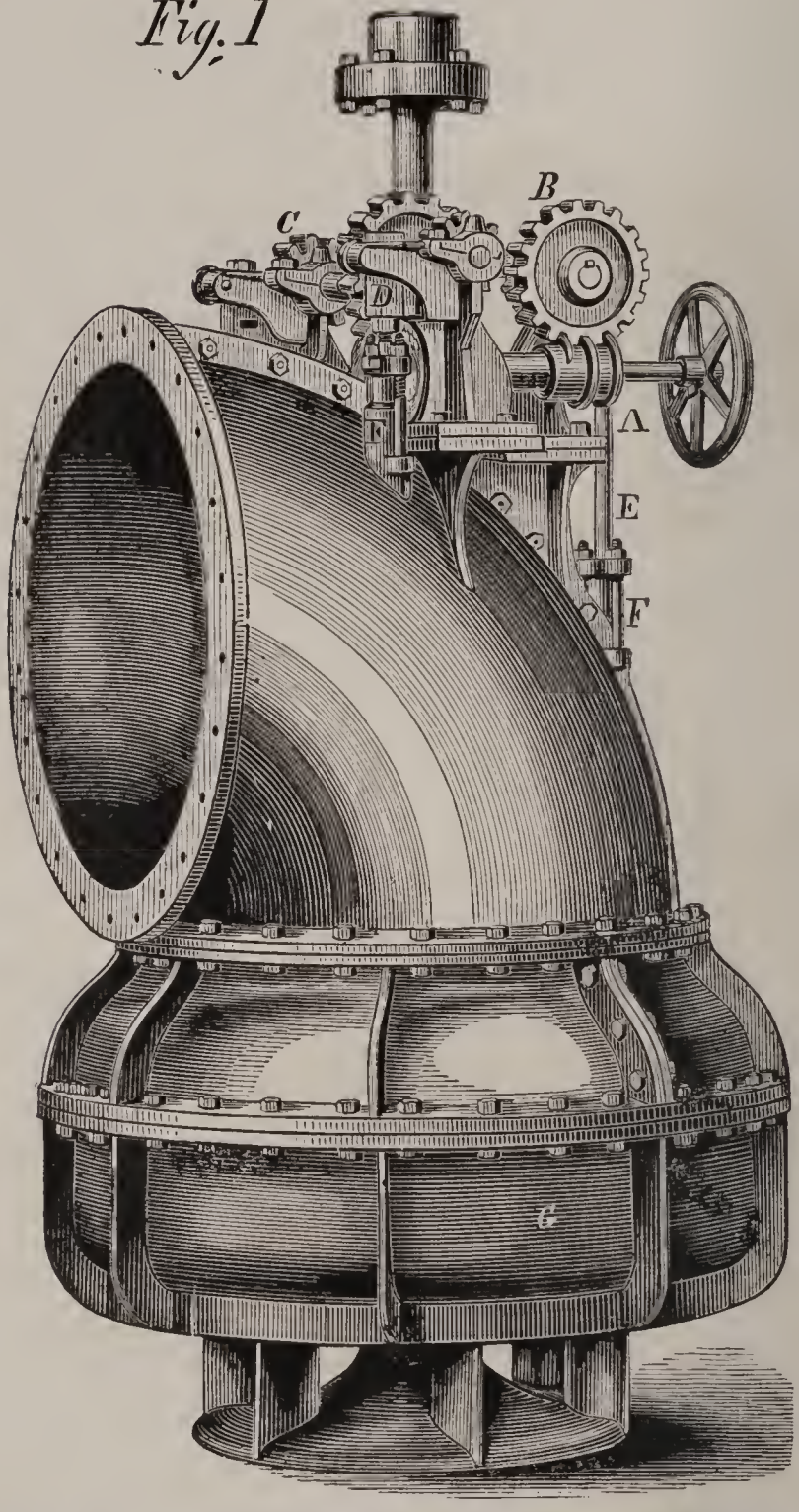
* 3.822 lbs. ft. per spindle = 145 spindles per horse-power.

SWAIN WHEEL,

IN QUARTER-TURN.

Fig. 1

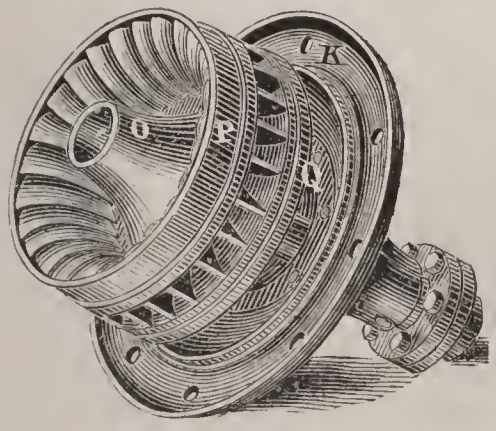


SWAIN TURBINE COMPANY,

NORTH CHELMSFORD, MASS.

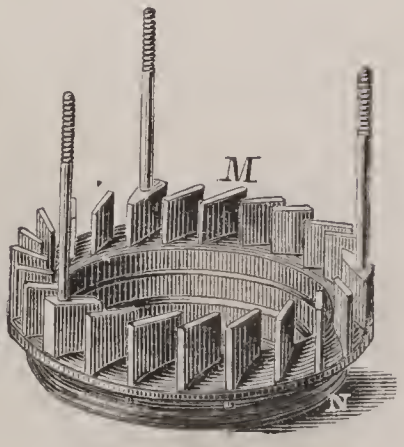
SWAIN'S

Fig. 4.



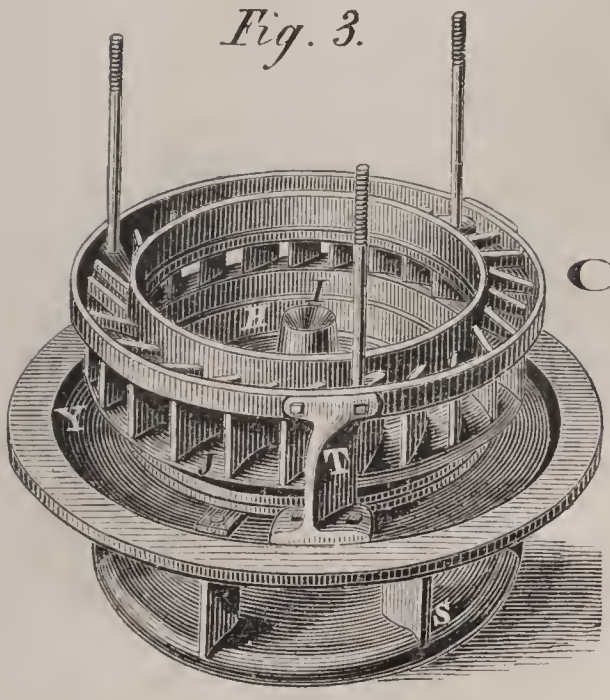
Wheel,

Fig. 6.



Gate,

Fig. 3.



Chamber,

Curb,

AND

Base.

FLUME WHEEL.

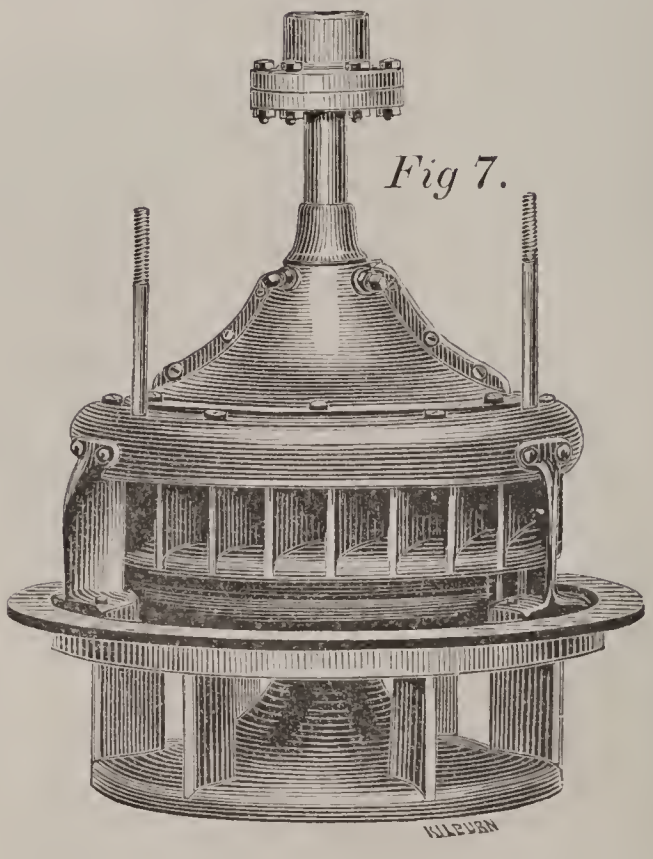
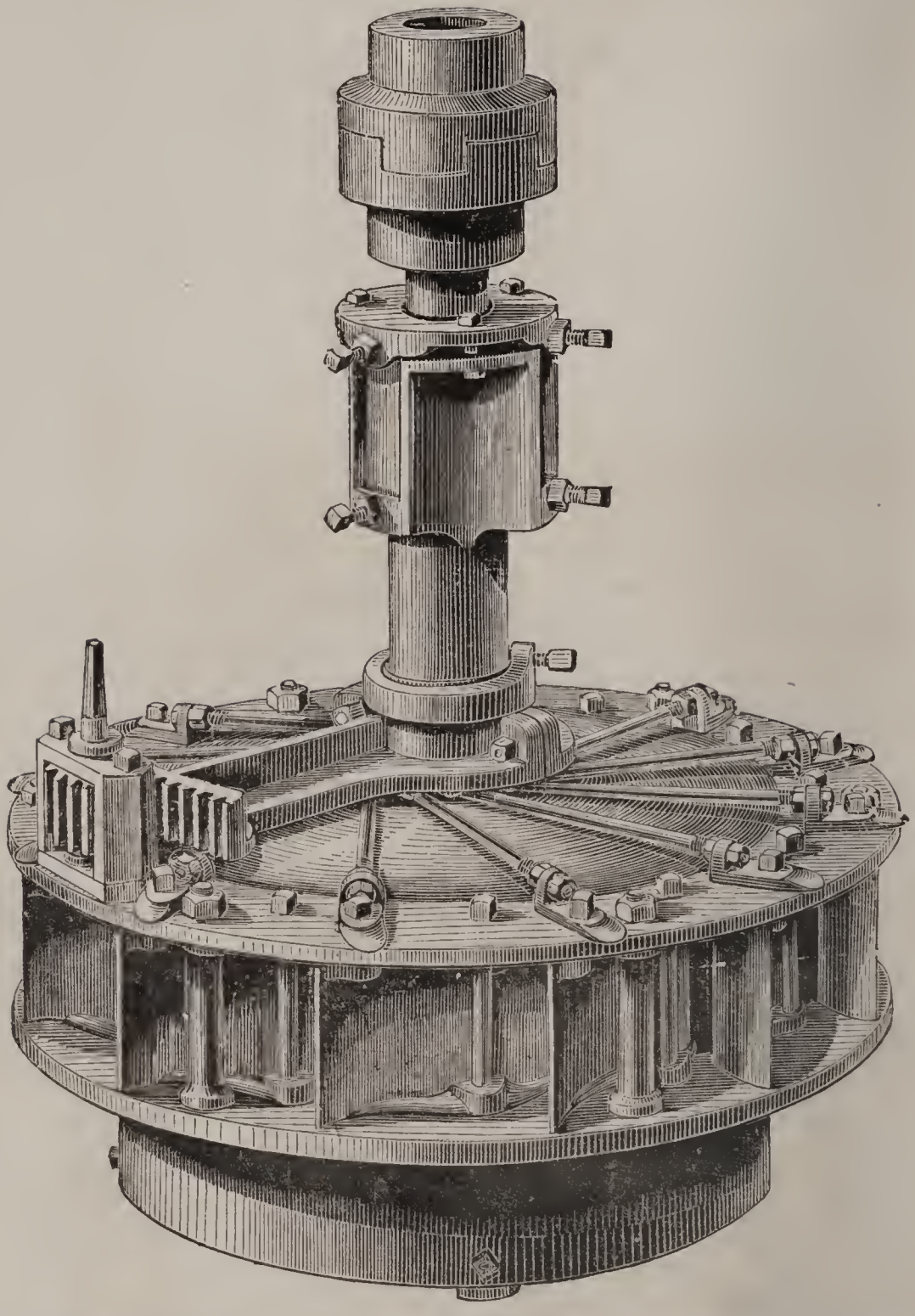


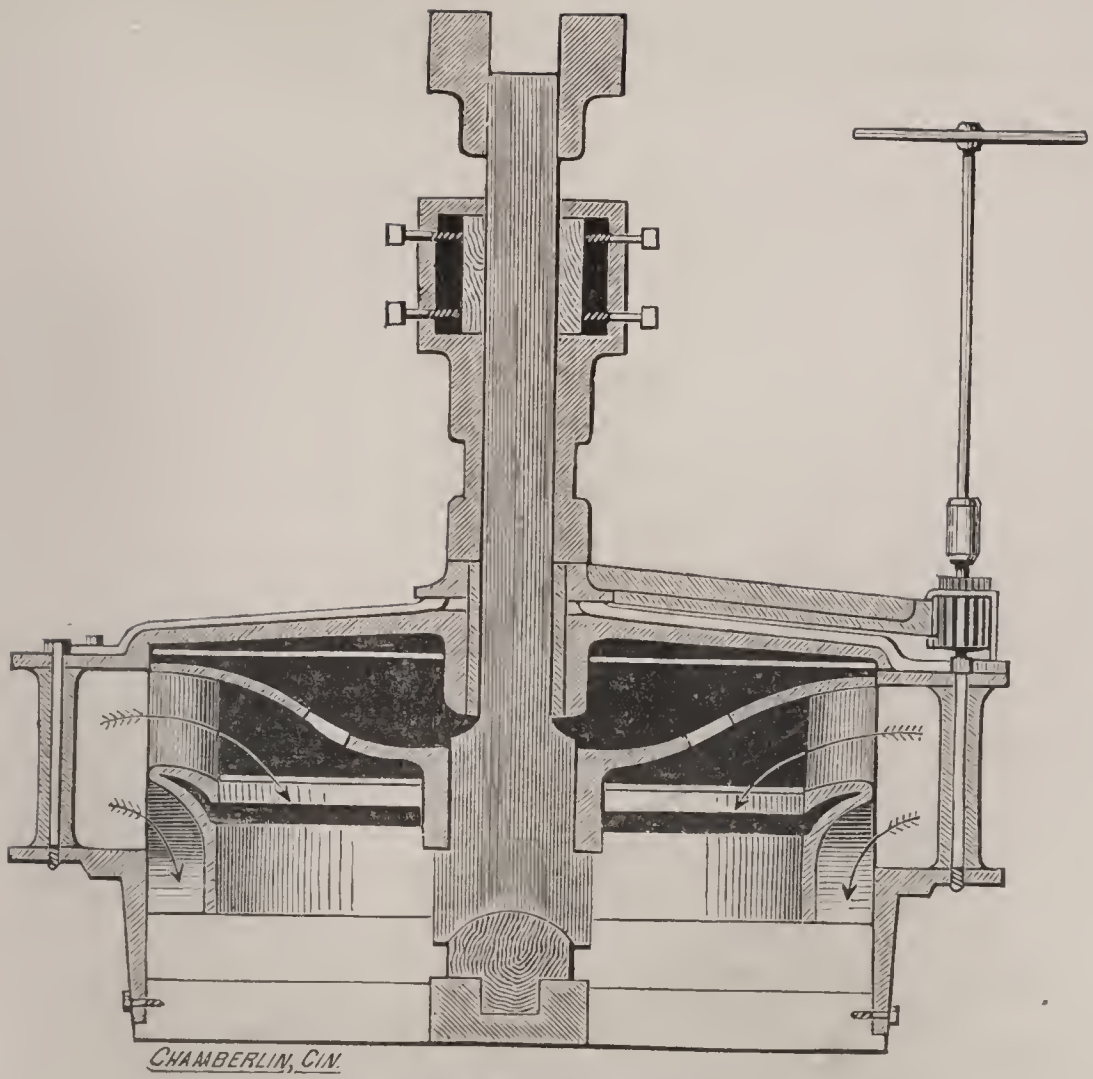
Fig 7.

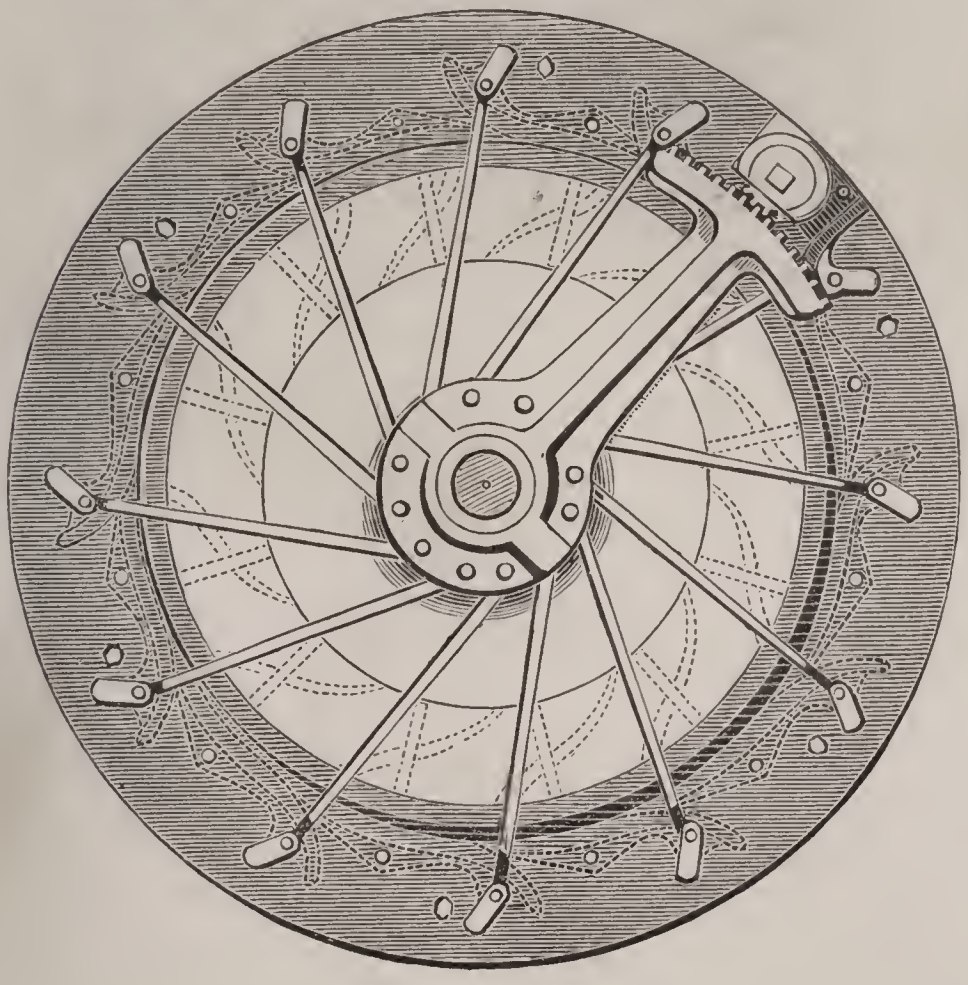
LEFFEL WHEEL,

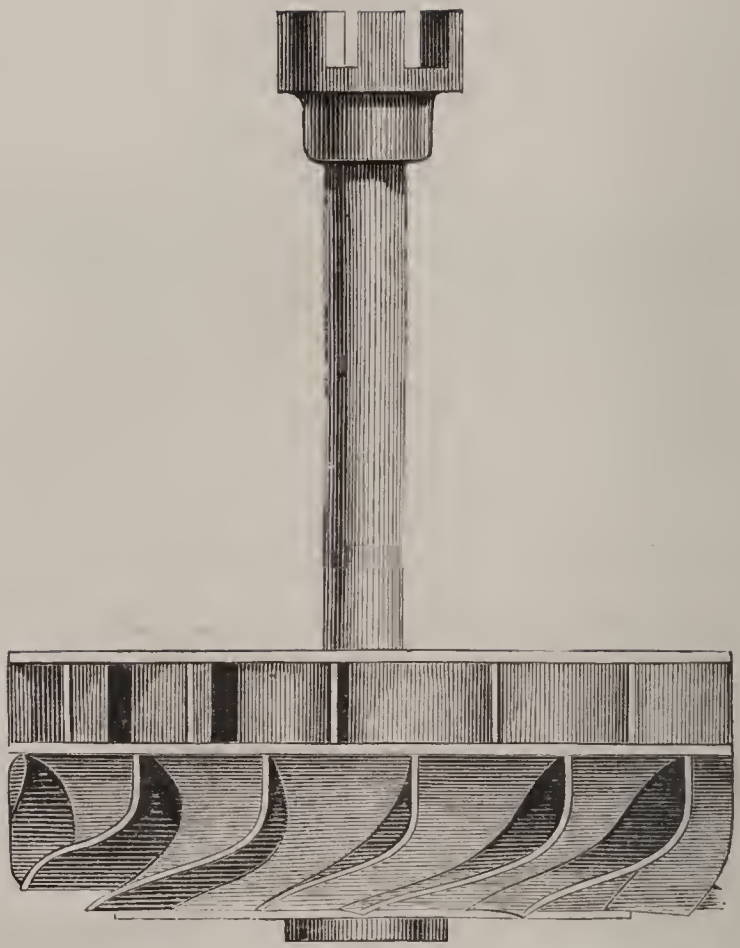


JAMES LEFFEL & CO.

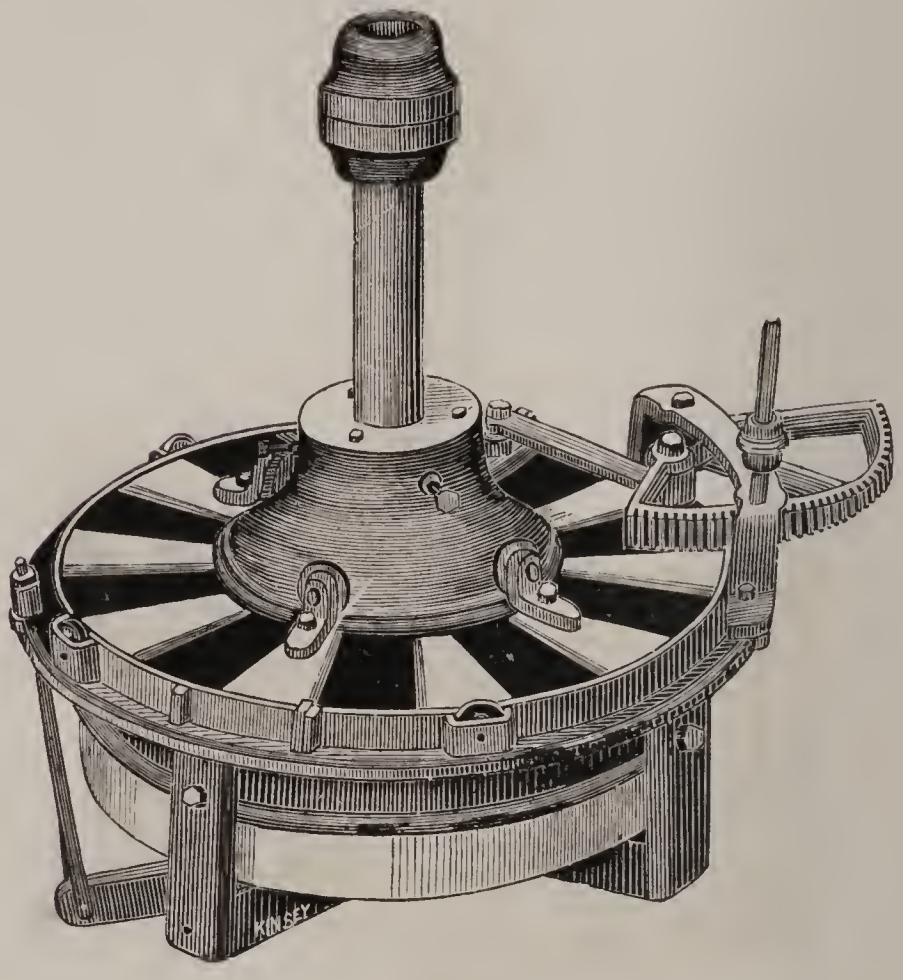
SPRINGFIELD, OHIO.


CHAMBERLIN, CIN.



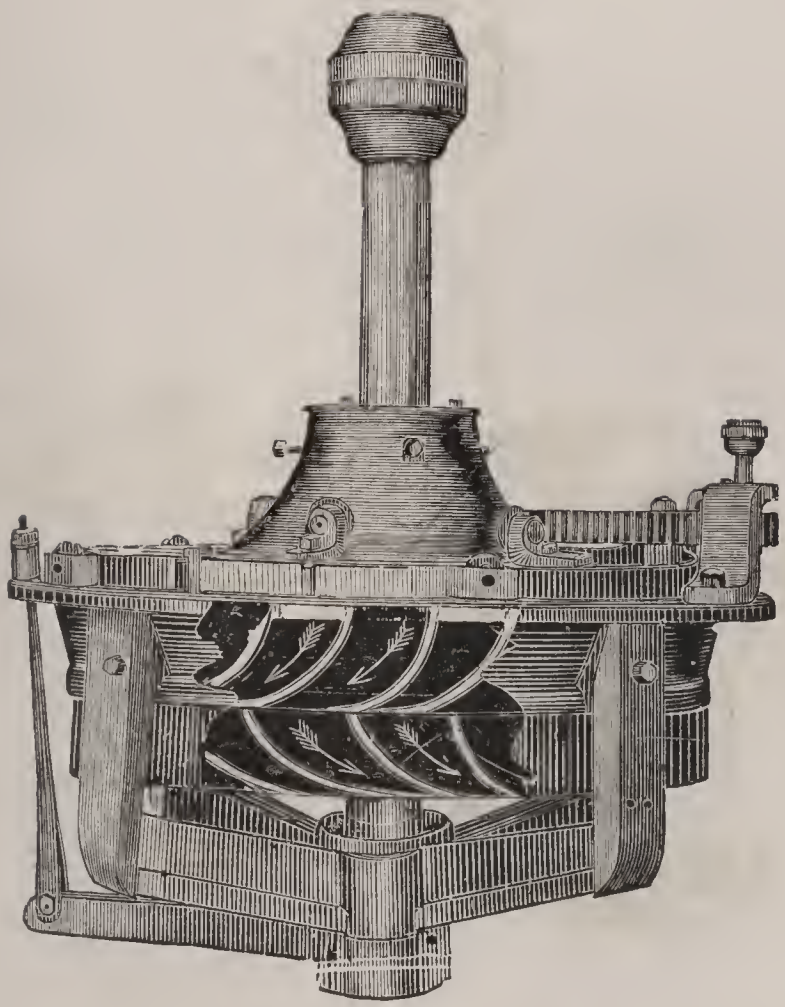


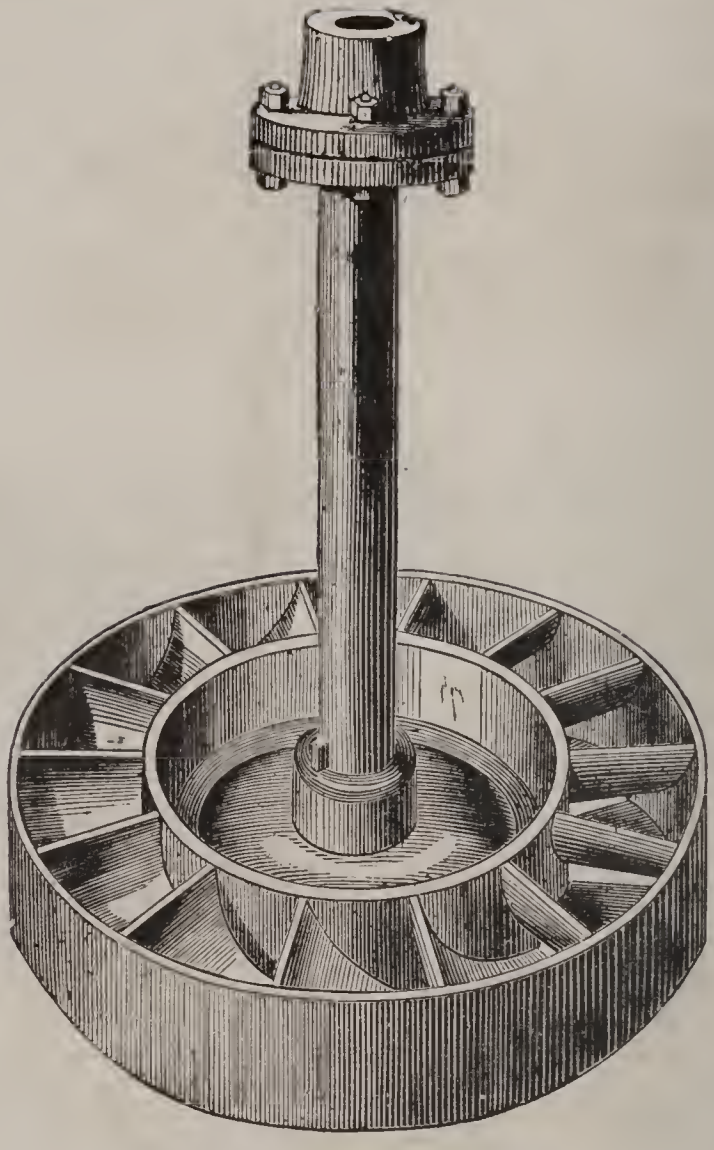
BODINE JONVAL.



BODINE MANUFACTURING CO.

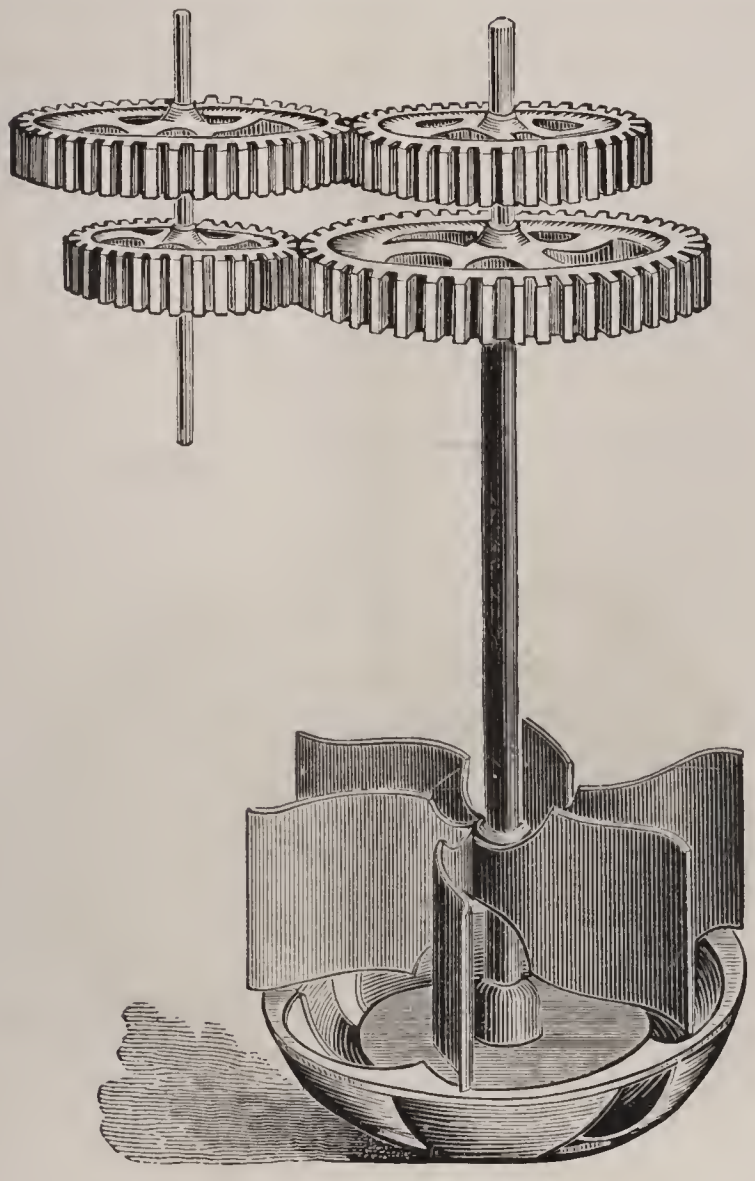
WESTFIELD, MASS.





WHEEL AND SHAFT

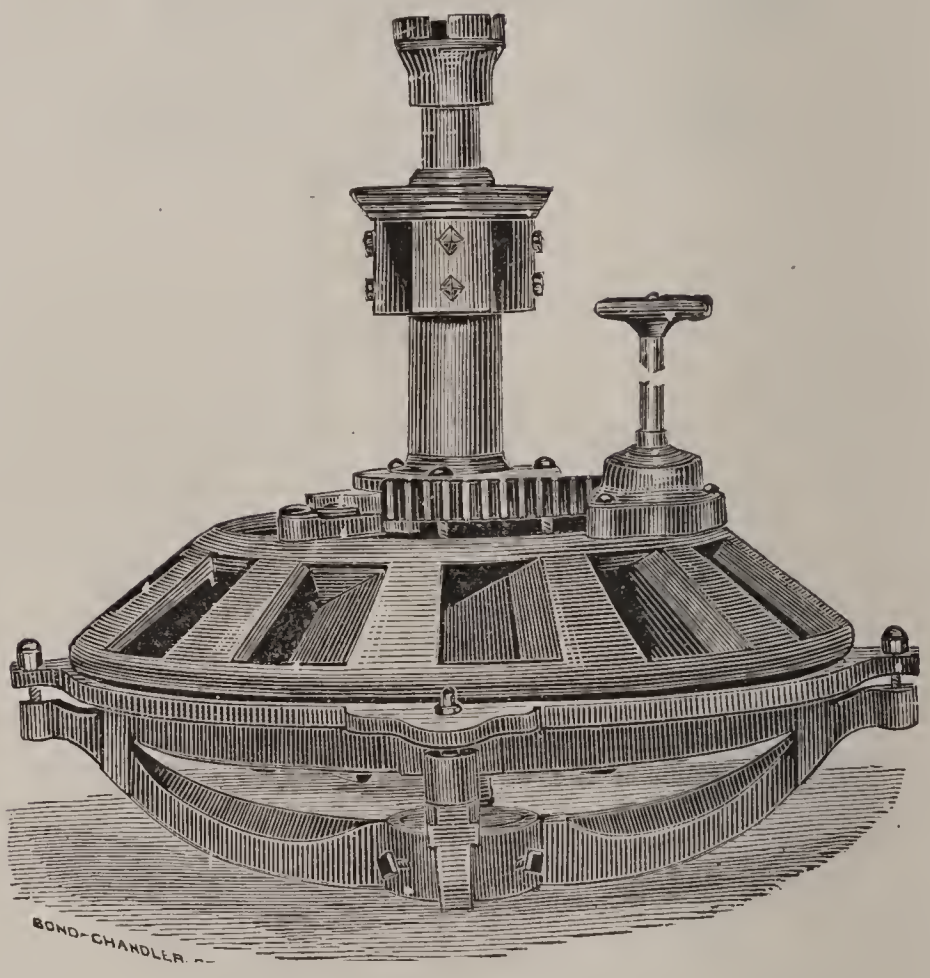
WYNKOOP WHEEL.



Wynkoop Double Power Water Wheel Company.

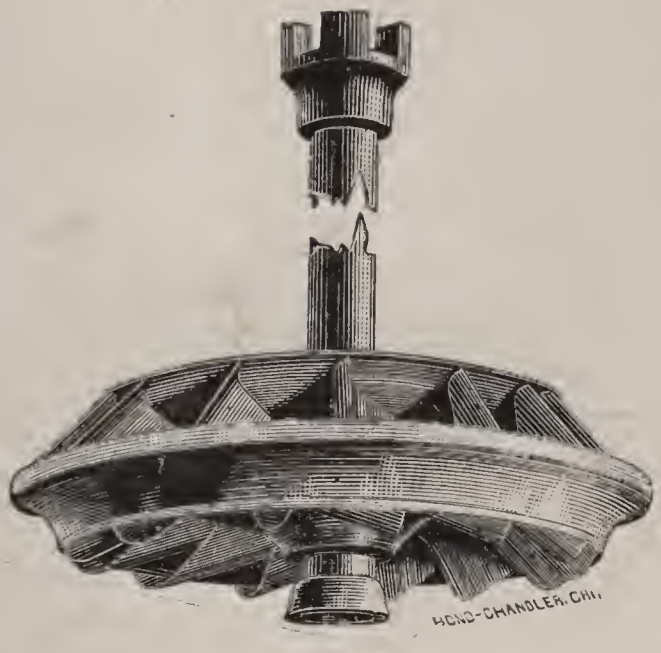
DETROIT, MICH.

HOUSTON WHEEL.



O. E. MERRILL & CO.,

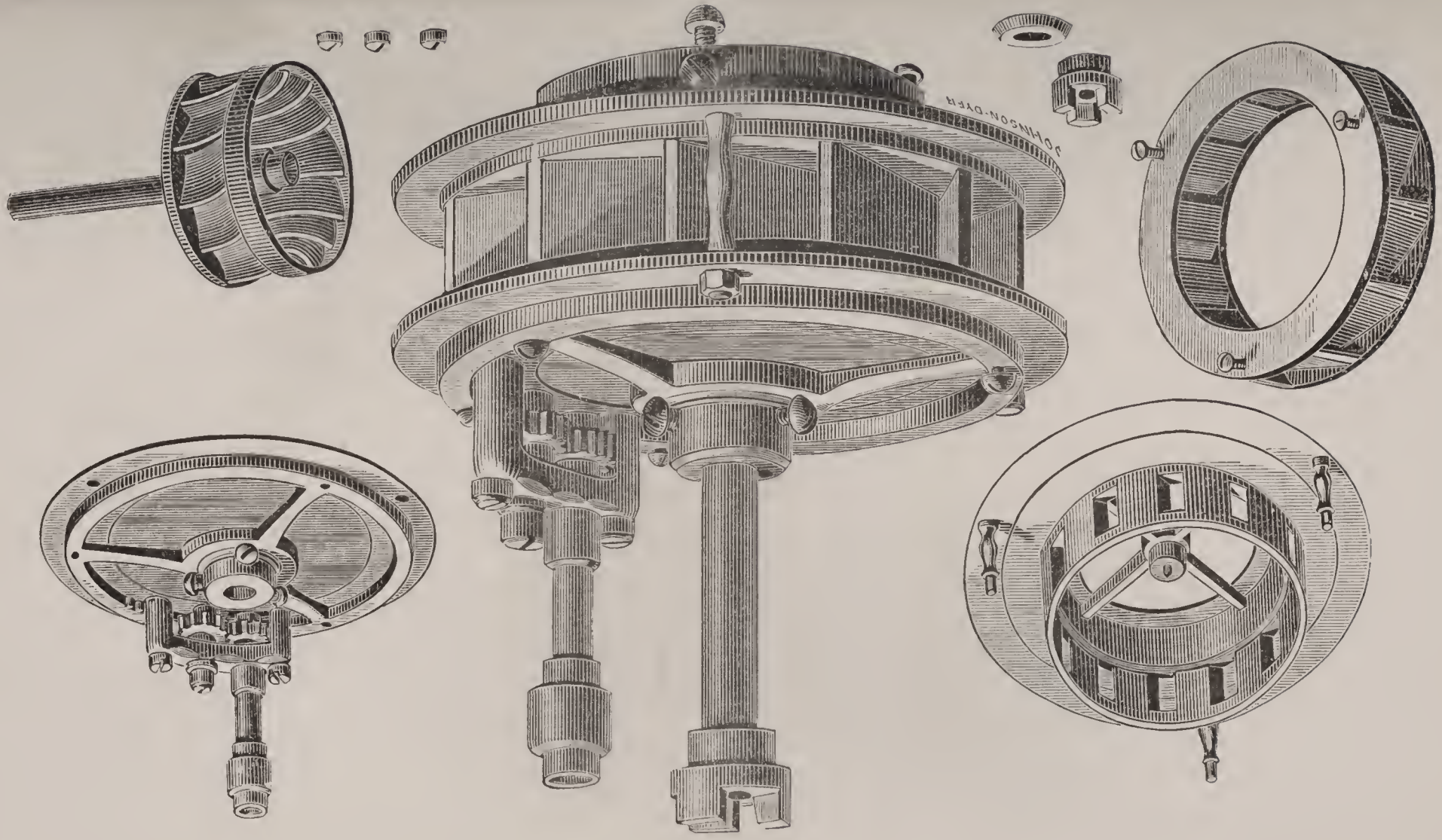
BELOIT, WIS.


HOND-CHANDLER. CHI.

STETSON WHEEL.

Putnam Machine Company,

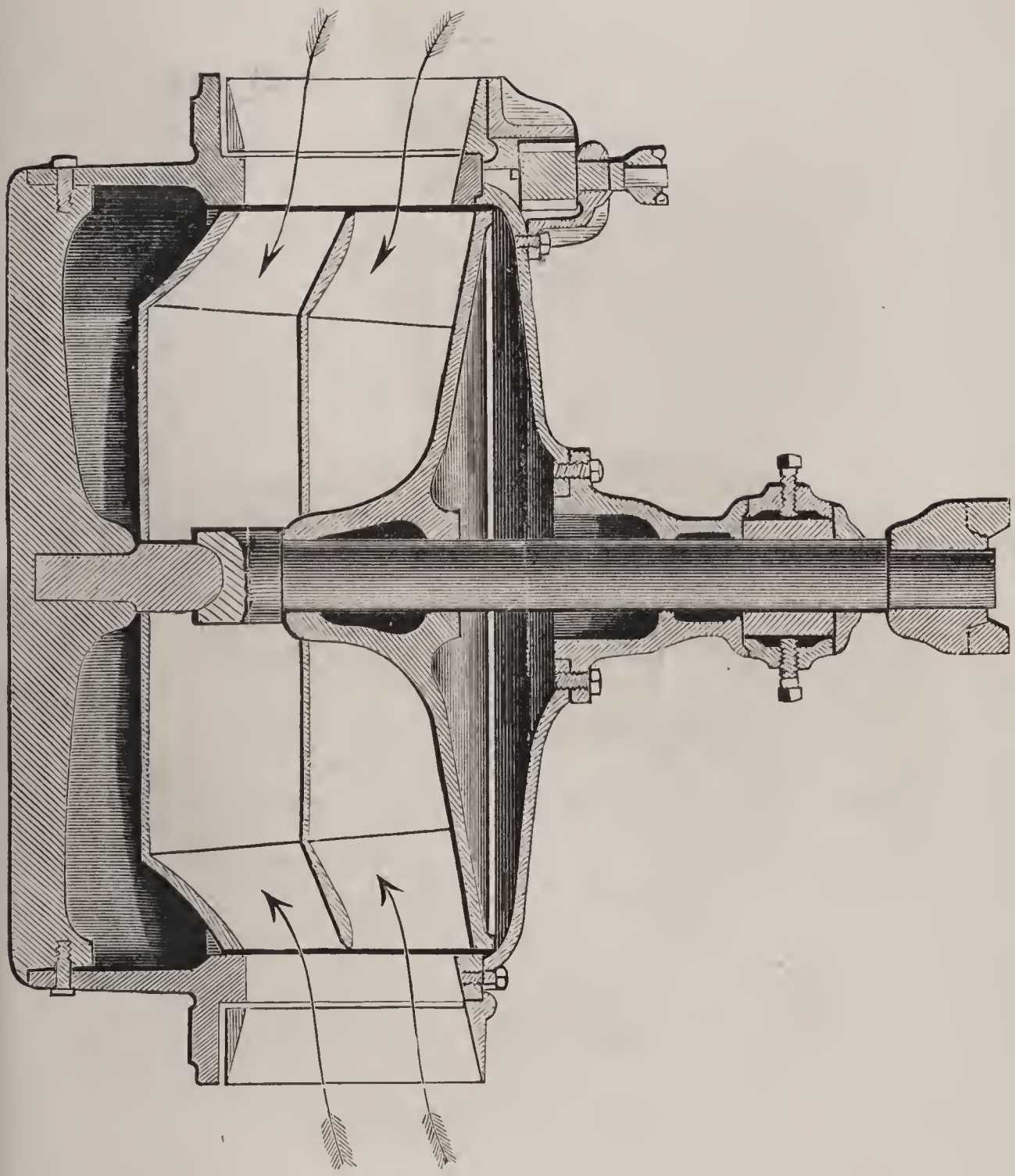
FITCHBURG, MASS.


JOHNSON-DYER

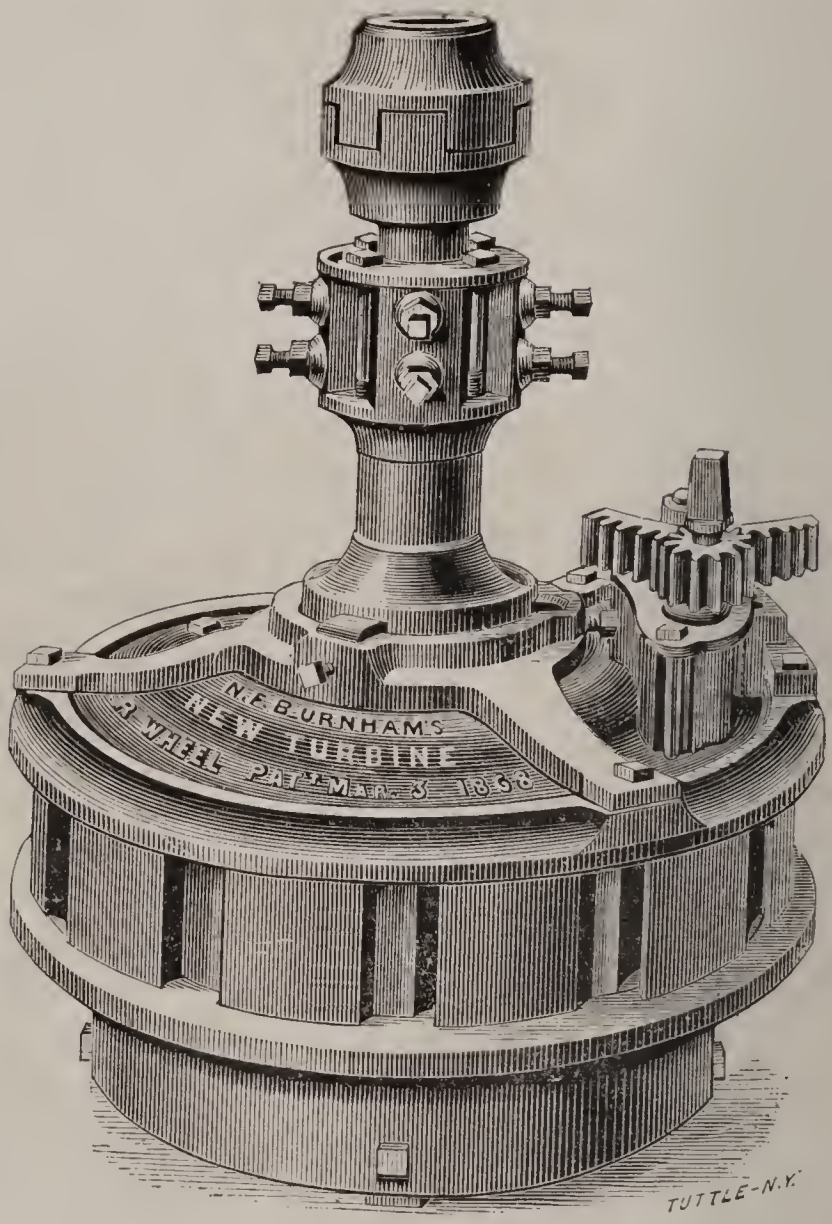
ECLIPSE TURBINE.

Stilwell & Bierce Man'fg Co.

DAYTON, OHIO.

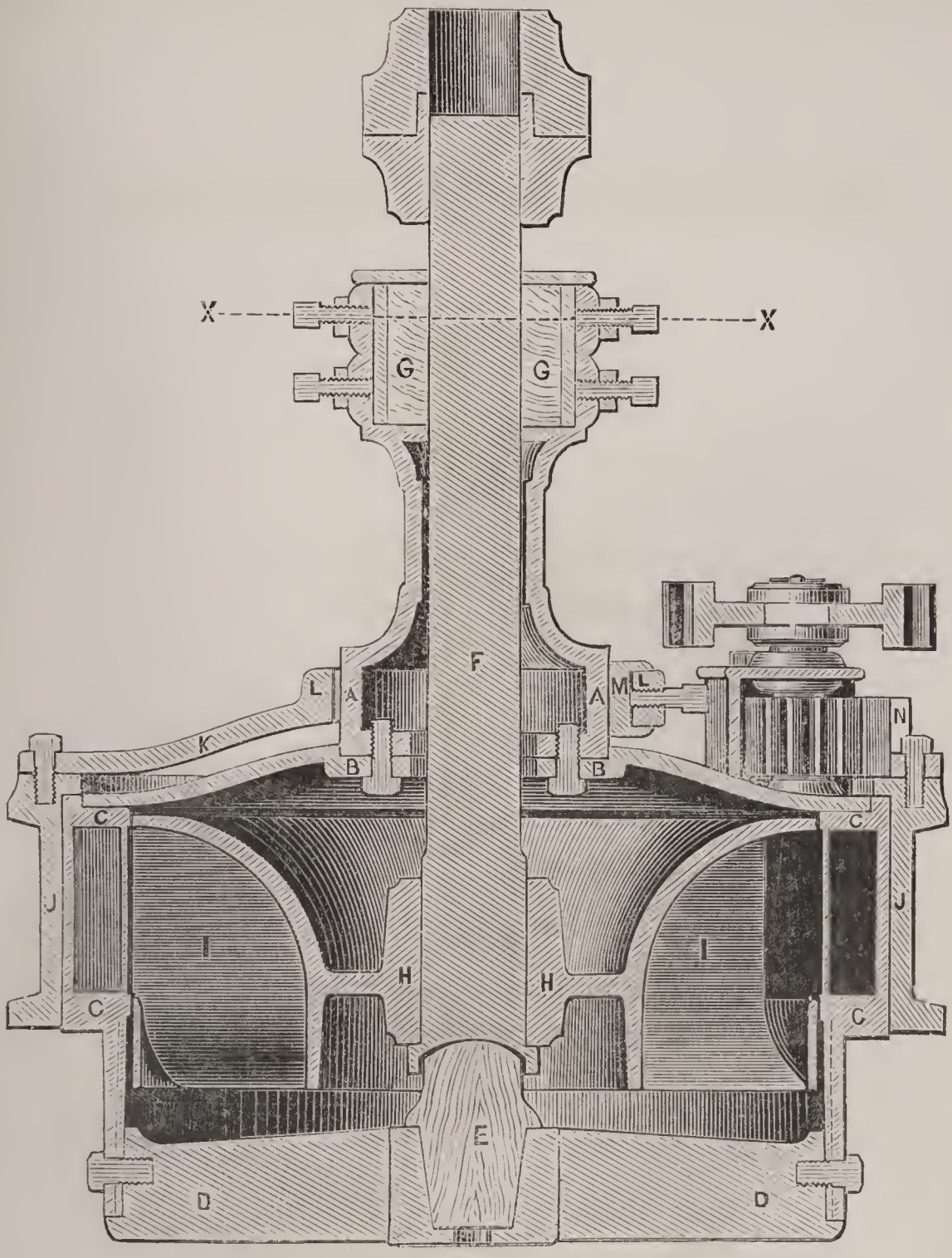


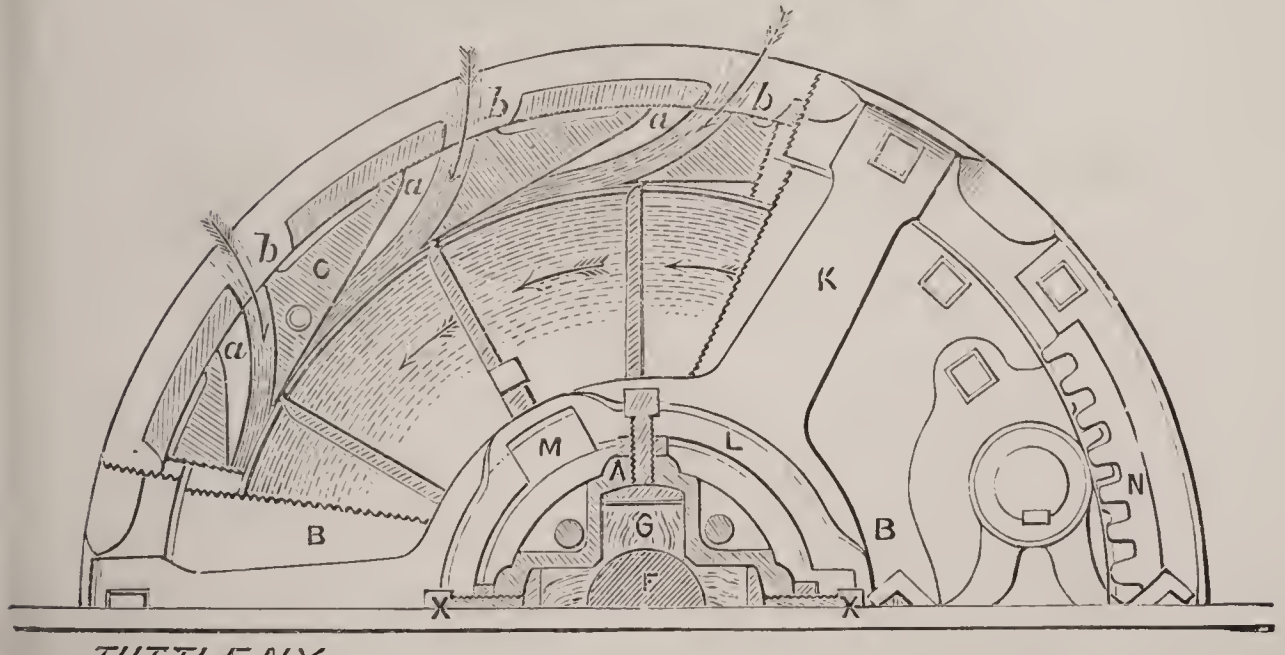
BURNHAM'S WHEEL,



N. F. BURNHAM,

YORK, PA.

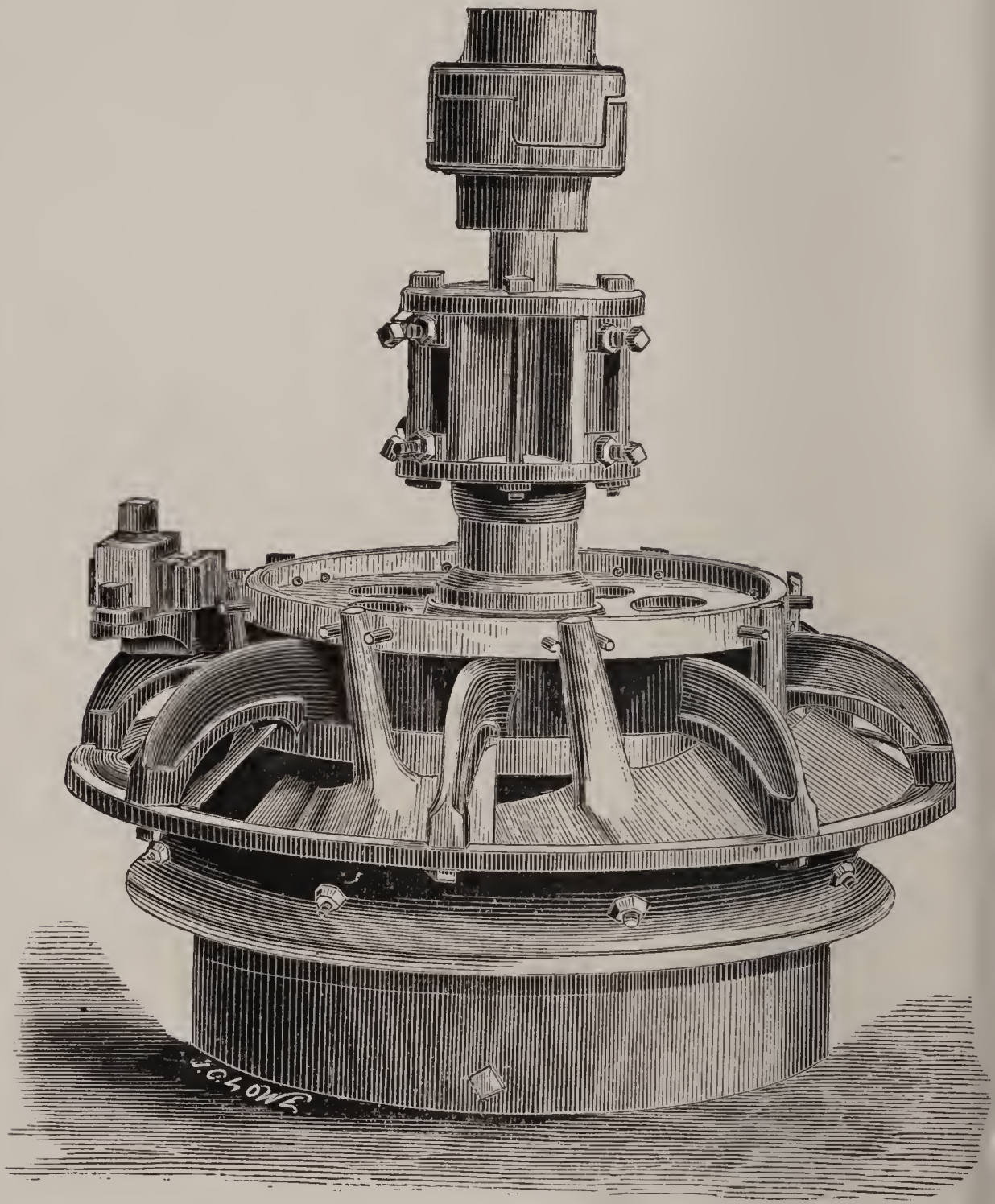




TUTTLE, N.Y.

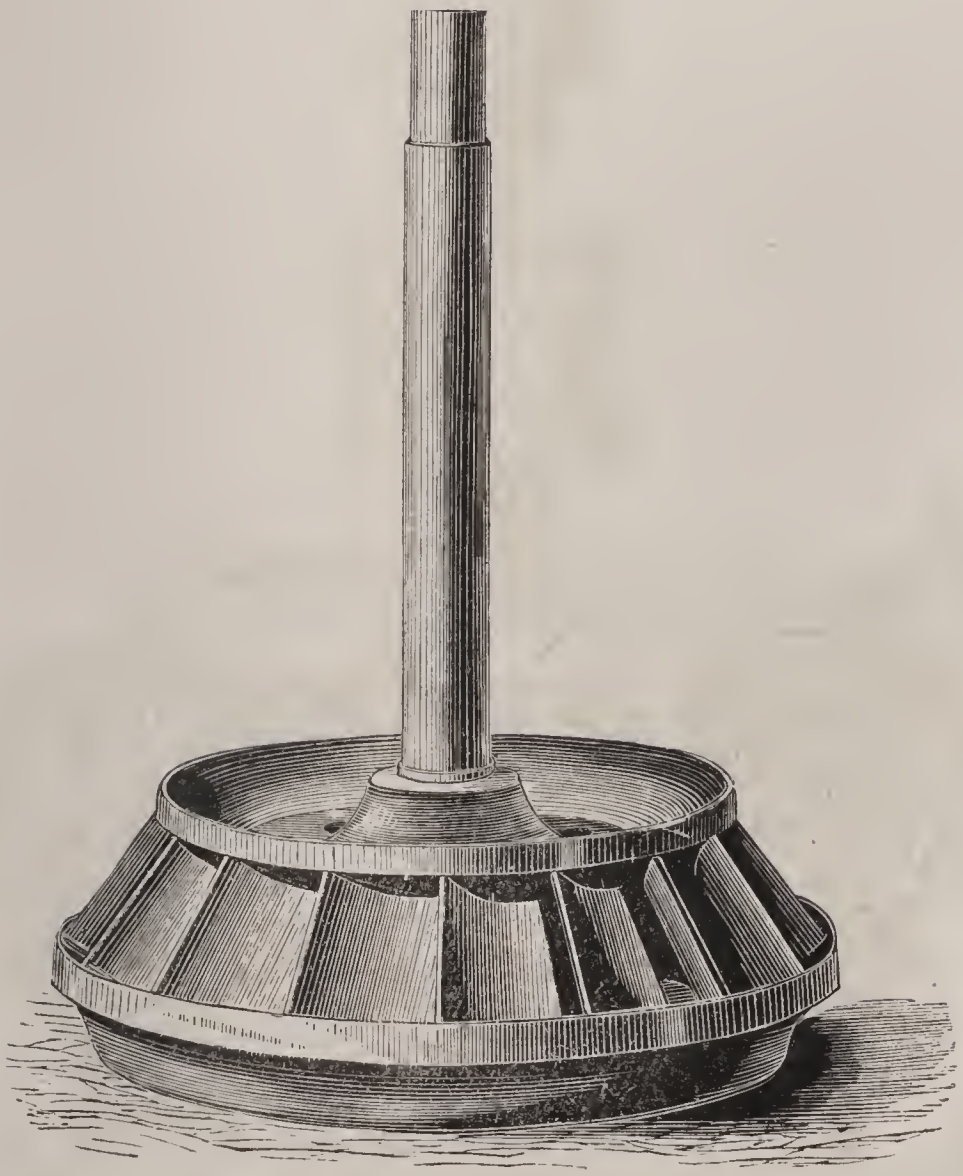
THOMPSON'S TURBINE,

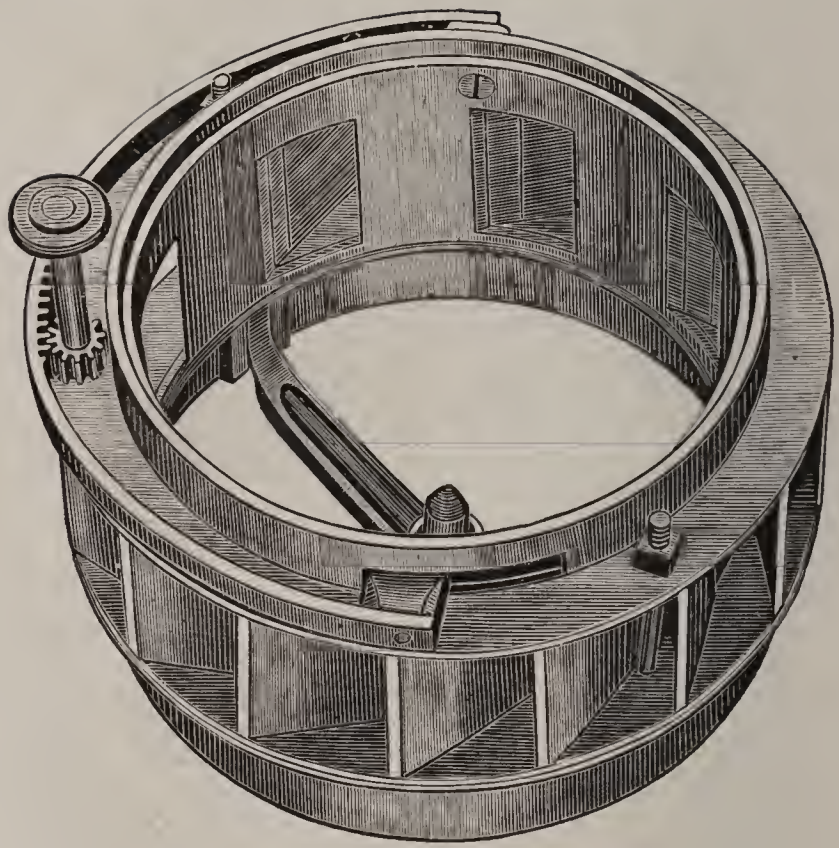
SPRINGFIELD, MO., and



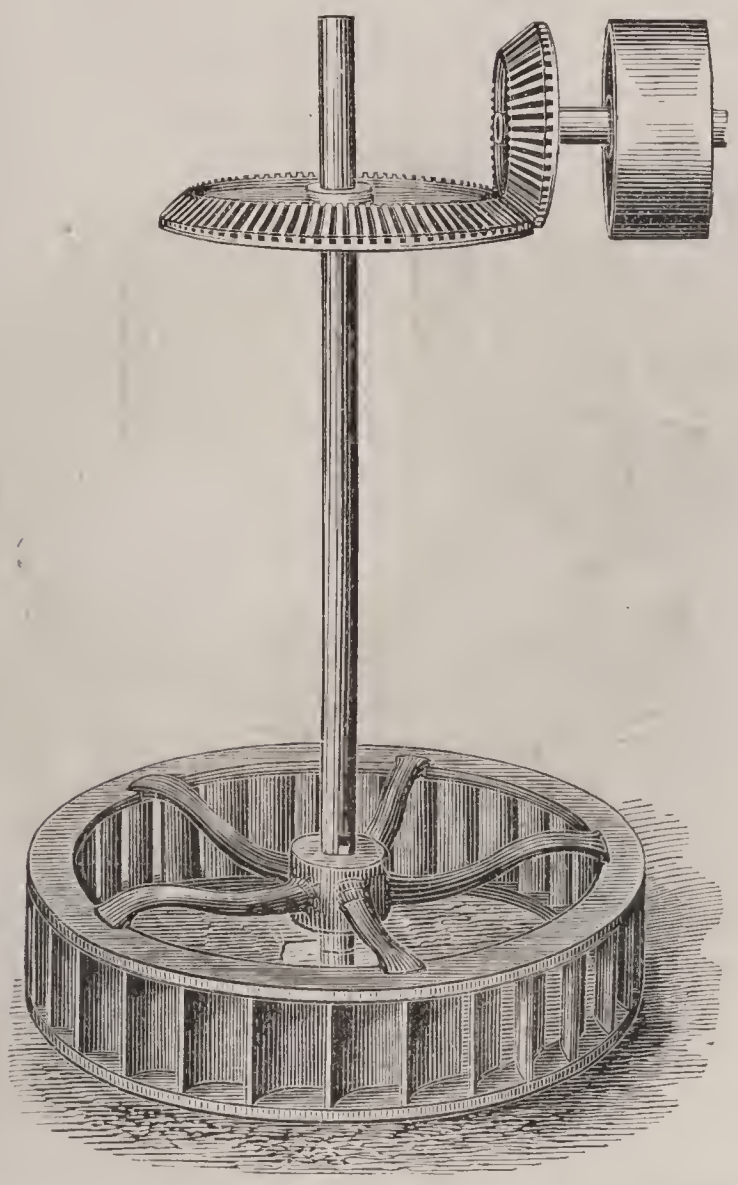
A. P. HOLCOMB,

SILVER CREEK, N. Y.





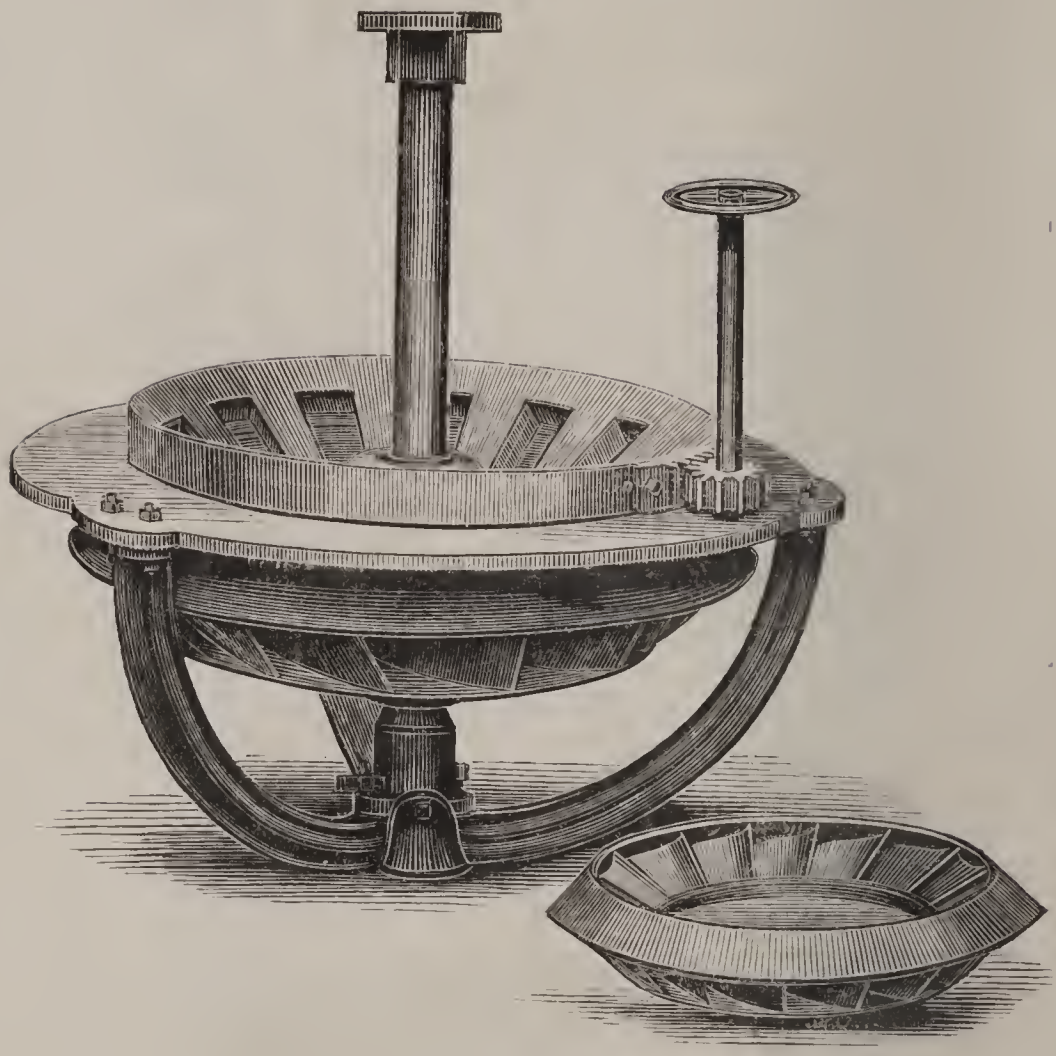
UPHAM'S WHEEL.



J. W. UPHAM,

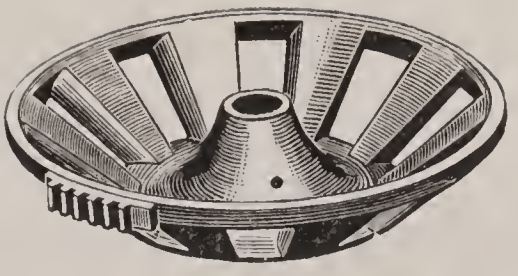
WORCESTER, MASS.

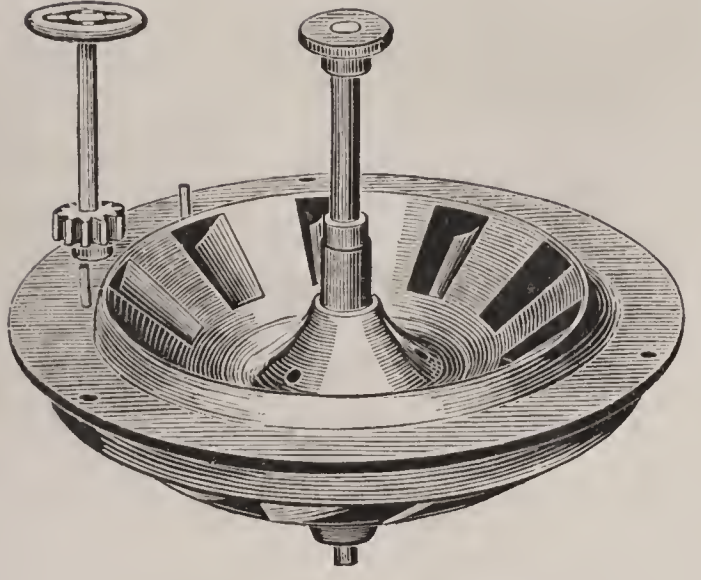
LIBBY'S WHEEL,



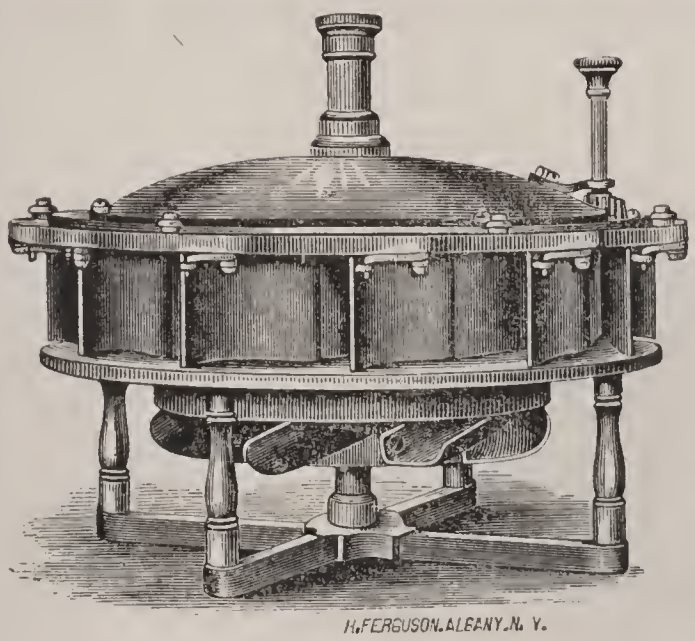
UPHAM & LIBBY,

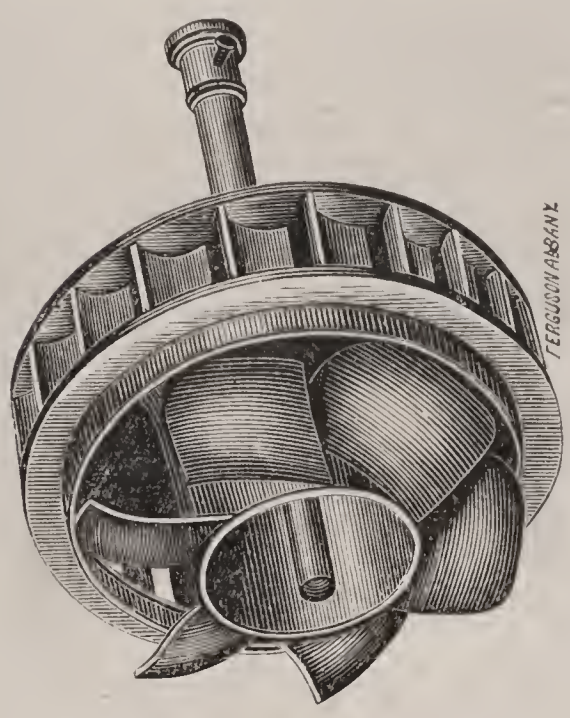
WORCESTER, MASS.





Barber's Combination.

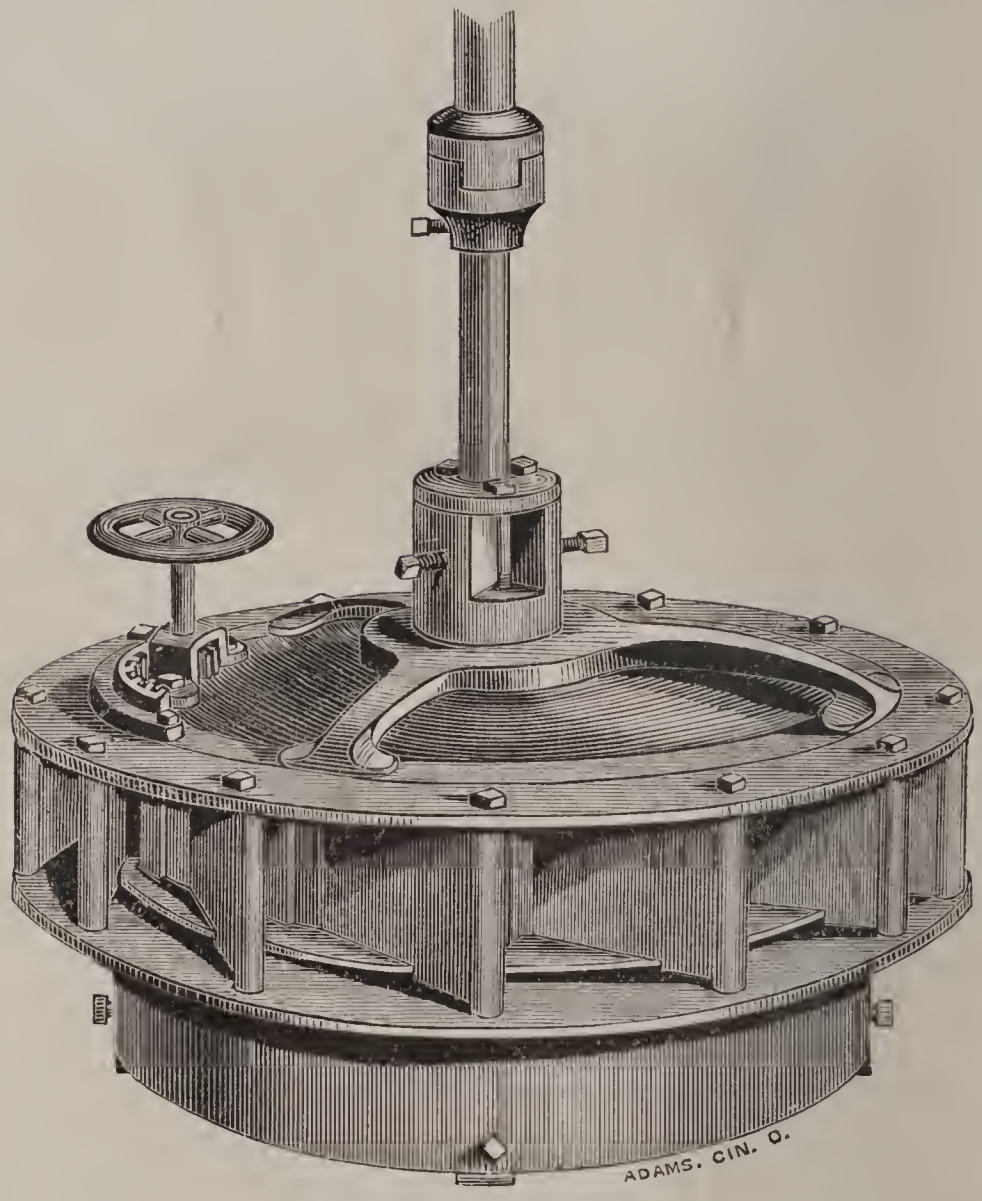




B. J. BARBER,

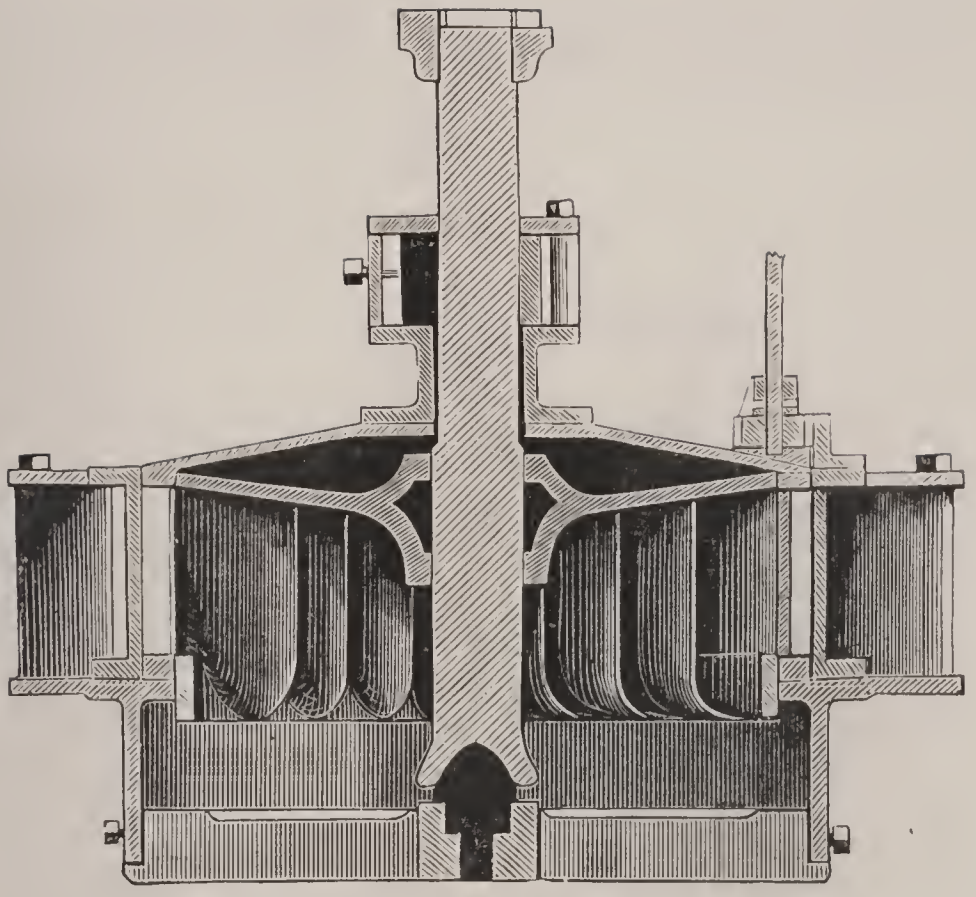
BALLSTON SPA, N. Y.

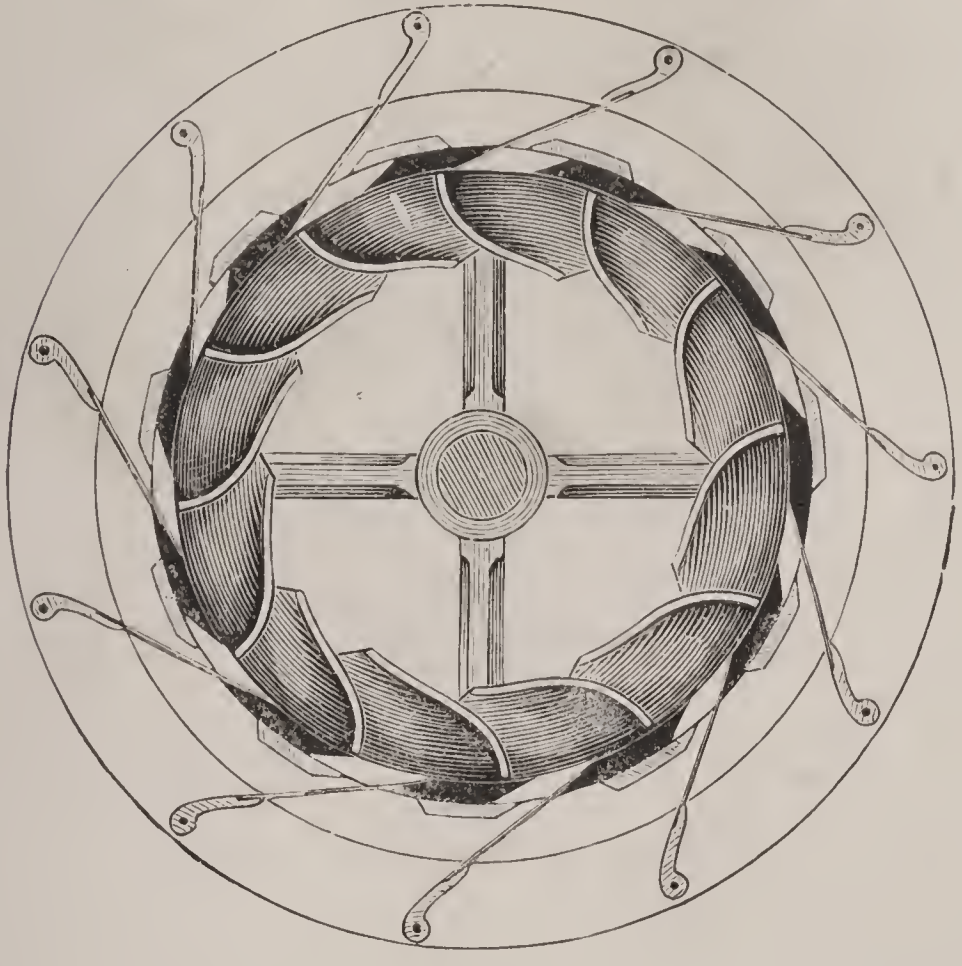
Bryson's Turret Wheel.



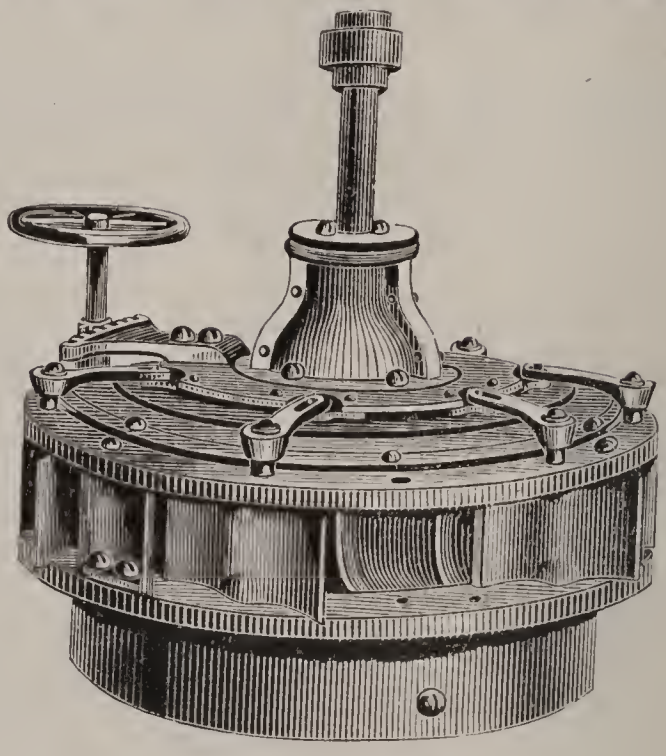
Greenwood Iron Works,

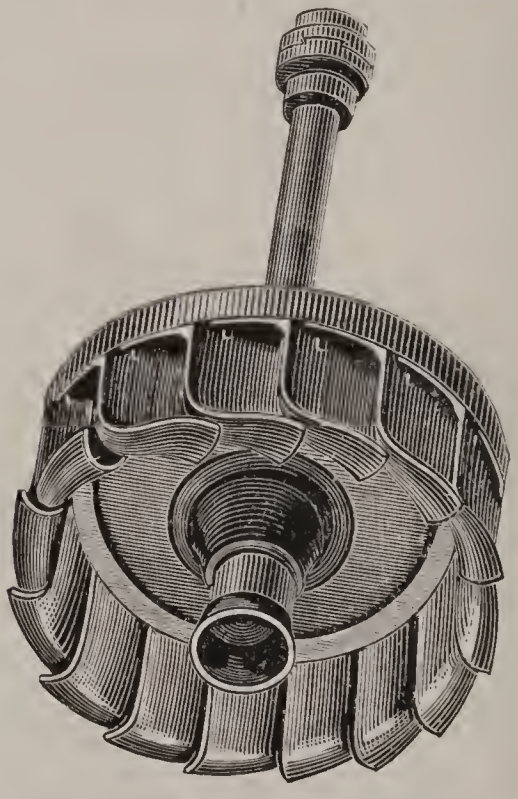
CINCINNATI, OHIO.





Cook's Giant Turbine.



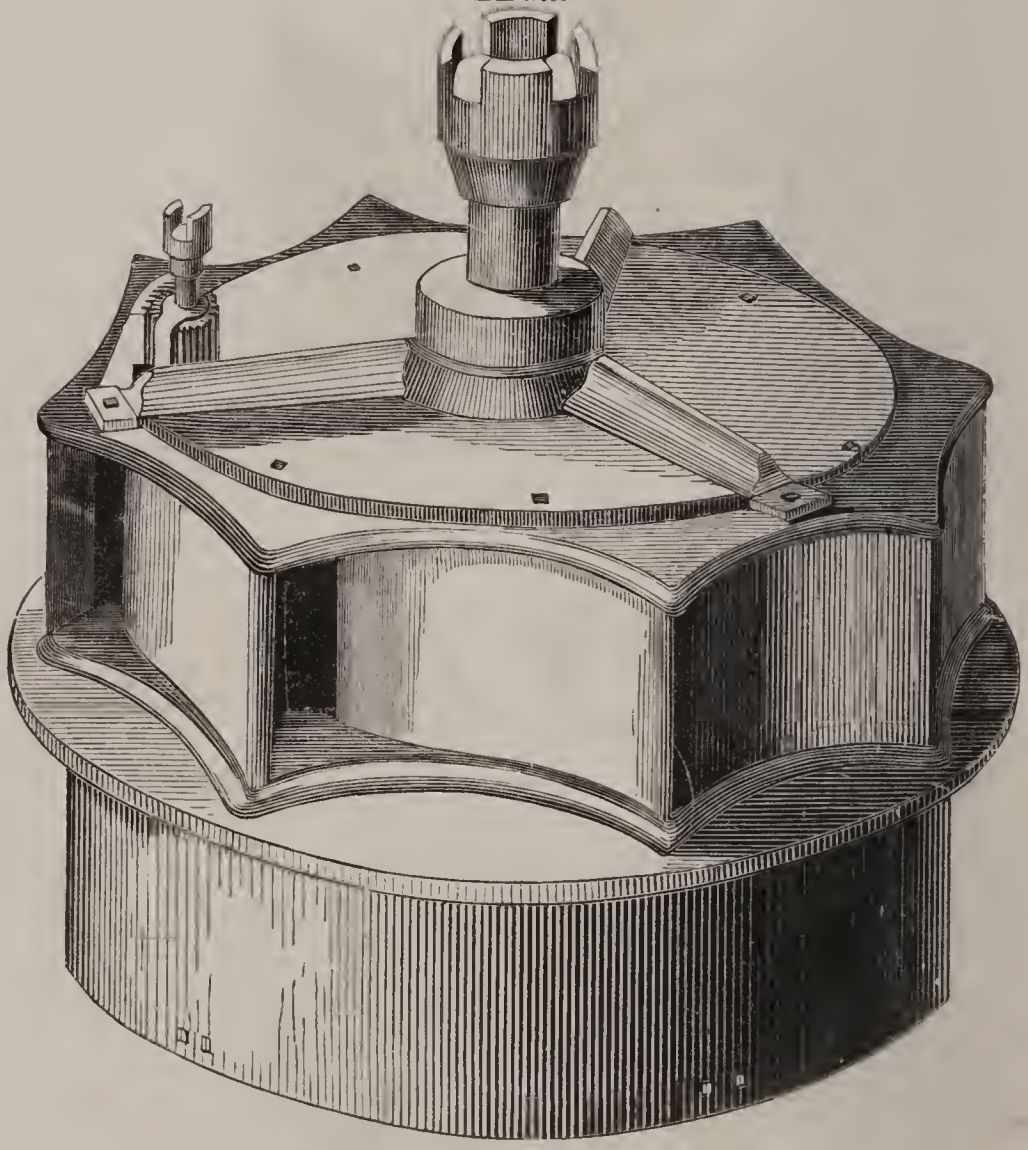


B. J. COLE & CO.,

LAKE VILLAGE, N. H.

RISDON TURBINE.

FIG. 1



THEODORE H. RISDON,

MOUNT HOLLY, N. J.

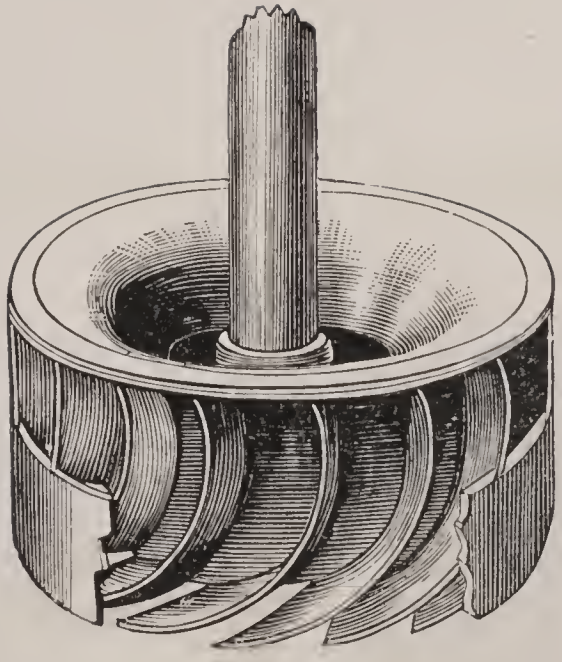
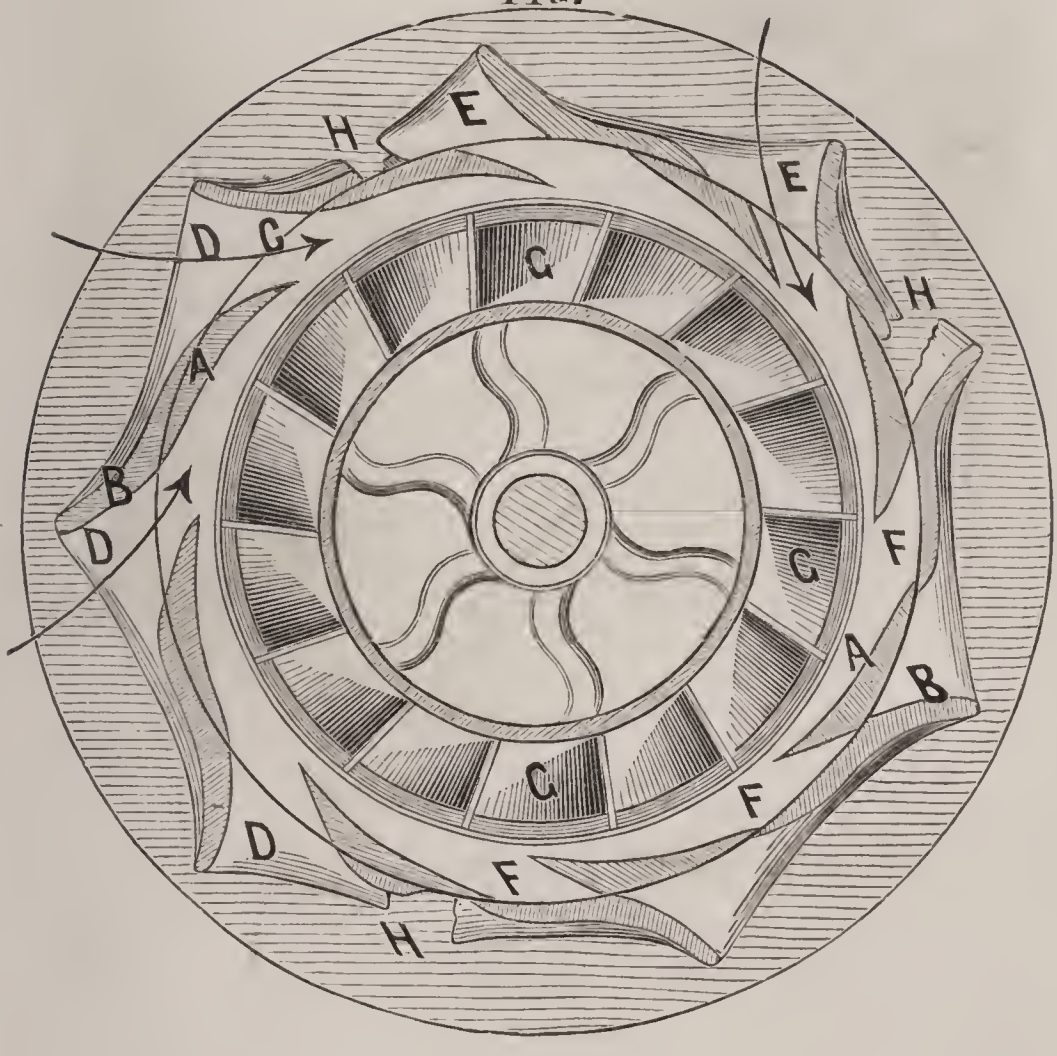


FIG.



REPORT

OF

Water-Wheel Tests,

AT LOWELL AND OTHER PLACES.

As is well known, an attempt has been made to procure a law to regulate the sale of Motors, Water-Wheels in particular. Efforts to that effect would have been continued, but recent experiments would seem to prove that the percentage of a wheel is not constant, but varies with the head under which it works; until that point is decided, such a law could be of little use.

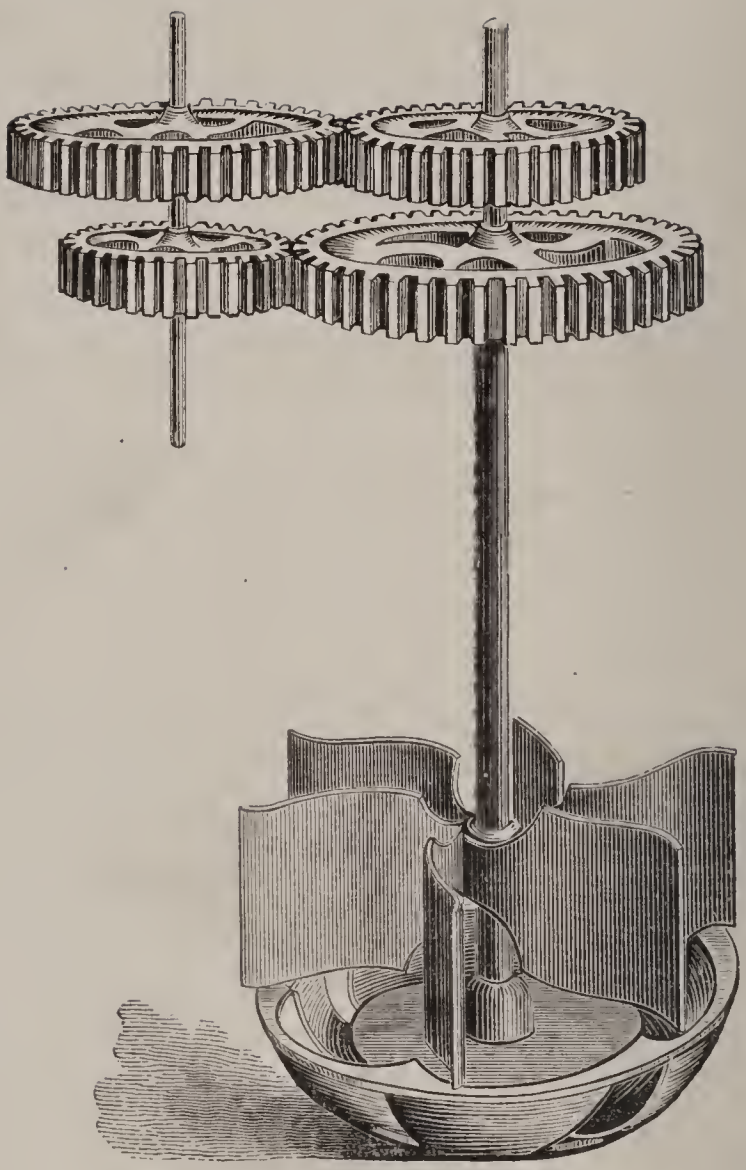
LOWELL, MASS:
STONE & HUSE, PRINTERS.
1872.

REPORT OF WATER-WHEEL TESTS,

AT LOWELL AND OTHER PLACES.

Early in the past season notice was given that the experiments, at the Lowell Testing Flume, would close for the season with November; but, at that date, twenty wheels remained untried, and the experiments were continued until the close of the year; then, to decide whether the percentage of a wheel remained the same under different heads, I went to Ballston Spa, N. Y., and Mount Holly, N. J., and tested wheels that had previously been tested here. The results obtained seem to show that much higher percentage can be obtained under a low than a high head.

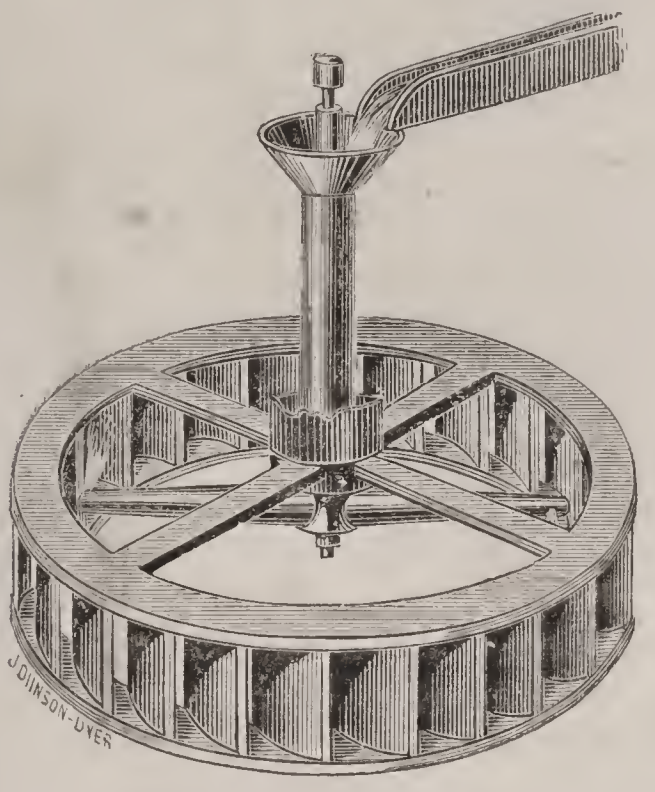
A description of all the wheels that I have tested would require too much room, and I will only refer to the peculiarities of a few. There seems to be a growing mania with wheel-builders to construct combination, or double wheels. The idea, old in itself, seems to have been revived by James Leffel at a time when it was difficult to find a really good wheel. The merits of his wheel, together with the indomitable energy of its builders, have rendered it one of the leading wheels in the country and too well known to require description here.



Wynkoop.

The combination shown above is upon an entirely different principle—a "Perpetual motion," if successful. This combination was placed in a curb similar to the one patented by W. S. Davis—only the gates all opened at once. Mr. Wynkoop claimed that the velocity of the water, by direct action, operated the upper wheel, then the *weight* of the water acted upon the re-action wheel below—thus obtaining double power from the water used; and, strange as it may seem, college professors, engineers, high school teachers and officials of various grades were found who were willing to endorse such claims; and a circular was published and circulated, containing the

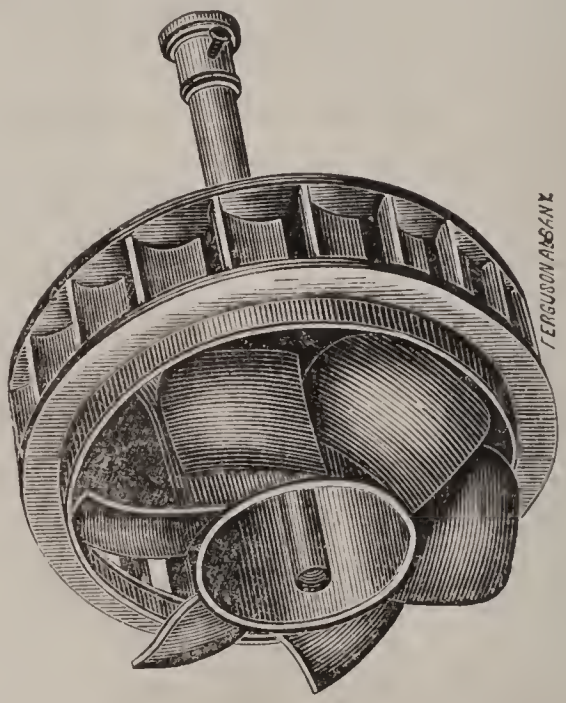
names of a score or more of influential persons, who stated that they had seen the wheel in operation and believed it gave one hundred and seventy-five if not two hundred per cent. of the power of the water used. When the combination was tested here it discharged so much more water than was expected, that the weir was too short and the water ran over the sides of the testing pit. The percentage due from the water passing the weir without allowance for that escaping over the sides of the pit, is given with the other wheels. Since testing the combination, I have received applications from three different States, by different parties, for terms for testing, identically, the same combination. An engraving of the Wynkoop, together with the results of test sent in reply, has in each case closed the correspondence.



The two, combined with gears at the top, like the Wynkoop.

A combination of the "Barker Mill," with a Fourneyron wheel, as represented above, also has admirers.

Three Mexicans, from the City of Mexico, came here to have such a combination tested, but abandoned it before doing so. The same combination has been placed in a mill within a few miles of this city, but the inventor has not yet concluded to enlarge his building facilities.

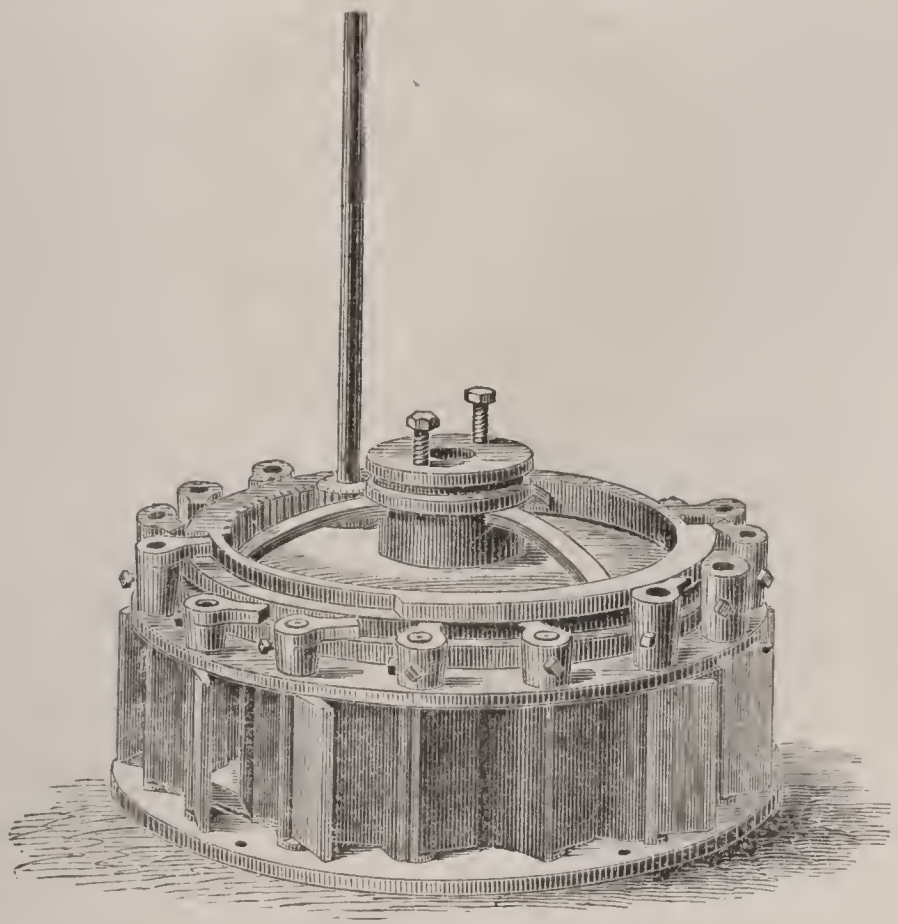


Barber's Combination.

B. J. Barber of Ballston Spa, N. Y., has made a combination that works well; so well indeed, as to cause manufacturers to think seriously of exchanging the expensive Fourneyron wheels as built by Mr. Boyden for it. The combination consists of a wheel like the Warren, (which was a favorite fifteen years ago, and now may be seen back of many a mill in New England, where it has been thrown to make room for better wheels,) and a reaction wheel underneath for the purpose of utilizing the remaining power of the water after it has passed the upper wheel. This is a theory upon which much time and money has been expended. Mr. Barber is working upon a more decisive plan than theorists generally do, for he has built a testing flume and procured complete testing apparatus in order to work understandingly.

Stilwell & Bierce Manufacturing Company of Dayton, Ohio, have also done the same in order to make the Eclipse (double) Turbine one of the best.

Gardiner Cox also furnished a wheel which he called double; it consisted of a core with a Jonval Wheel, around it, at the bottom, the buckets being continued by sheet iron spirals around the core to its top, forming a twelve-threaded screw—the pitch being twelve degrees from line of rotation.



W. S. Davis' Curb.

The curb represented above was tried, to ascertain whether better "part gate" results could be obtained by opening a certain number of gates, from two to sixteen, than by opening the whole, proportionally; with the wheels tried, the results were not favorable, but the principle would seem to be correct, for in testing a Houston wheel, with some of the openings stopped with blocks of wood, it will

be seen that very high results were obtained for the proportion of water used.

Much has been said about highly finished wheels being sent here for trial. There is little foundation for such rumors. In 1869 the Messrs. Leffel sent wheels that were constructed for the purpose as they had a right to do under the conditions imposed; as a rule, those sending wheels have been very fair, and most certainly, the wheels that have given the best results have not been those of the best finish. It is quite common for some manufacturers to say that "little reliance can be placed in reports of tests;" such statements have a very injurious influence, and if there is any cause for such, it rests with themselves. The comparative merits of any wheel may be determined at a Testing Flume as perfectly as groceries can be weighed, but the cause for discrepancies is that builders seldom construct two wheels exactly alike, so that if Mr. Smith has a "Samson Turbine" that gives satisfactory results, there is no certainty that Mr. Jones will get one of that make that will do the same, and here may be found the cause why references are of little value. The better class of builders, feeling the inconveniences arising from such a system, are having their wheels tested, not only to determine their merits, but experimentally for improvement, while another class sell their wheels on the reputation of some well-known wheel that has been tested, but the same builder while experimenting will vary more than twenty per cent., consequently, manufacturers should understand that a resemblance is no guarantee of merit, and their only chance for obtaining a reliable wheel is to buy of responsible parties who are ready, at any time, to prove by actual trial that their wheels are what they are represented to be—a strict observance of such a rule would add at least twenty-five per cent. useful effect to the water power of Massachusetts.

An examination of the results obtained while testing N. F. Burnham's wheel will show the accuracy with which it can be done. The wheel was first tested, the shaft being made rigid with faced couplings bolted together; it was then taken out, the face couplings exchanged for clutch couplings, then tested again, afterwards taken out of the Flume, then taken apart, the buckets filed to an edge, faced couplings again fitted on, and the shaft where it worked in the upper bearing filed smaller, then tested the third time.

Stetson's first wheel, tested 1870, was tested the past season to decide whether a decked Flume is equally as effective as an open Flume; it will be seen that the highest result was obtained in the decked Flume, but it had four hundred pounds less weight of shafting to carry.

In making the experiments to determine the loss of power in transmission through gears, mitre gears twenty-seven inches in diameter, five-inch face, fifty-seven teeth, were used on wheel and "jack-shaft," the last being six feet in length and three inches in diameter; a Spur gear twenty-four inches in diameter, four and one-half inch face, forty-four teeth, was secured upon the "jack-shaft," which worked into another gear of the same size upon a second horizontal shaft, same size and length as the first, the second representing the main line of shafting through a mill, both horizontal shafts worked in common babbited bearings. The Dynamometer was placed upon the end of the shaft representing the main line, and the wheel tested through the two pairs of gears; the second shaft was then removed, the Dynamometer applied to the end of the "jack-shaft," and the wheel was then tested through the Mitre gears only, then the "jack-shaft" was removed, the gear taken from the top of the wheel shaft, the Dynamometer applied at the same point, and the wheel tested in the usual manner; the tests upon the wheel shaft and

the shaft representing main line were perfectly steady and reliable. The test upon the "jack-shaft" was made at noon under a higher head, and the end of the shaft was too small for the hub of the Dynamometer, causing it to run eccentrically, and the test was not so good. I propose the coming season to make a more thorough trial of such tests with different proportioned gears.

The reported part gate tests were taken when the wheels were running at about the same speed as when the best whole gate results were obtained; and three-fourths, one-half, one-fourth, &c., gate, designate the proportions of water discharged and not the openings of the gate.

NAME.	Size.	REMARKS.	Ft. Head.	PERCENTAGE OF PART GATE.					WHOLE GATE.	
				1/4	1/2	5/8	3/4	7/8	H. Power	Per cent.
Swain	42 in.	In "Quarter turn"	14.25	.....	.....	.....	.....	.....	63.00	82.2
"	36	" " "	15.10	.....	.....	.....	.....	.....	46.39	77.56
"	36	Wood Flume	15.10	13.10	43.20	.....	67 00	7[.90	45.40	74.60
"	30	" "	15.41	.....	47.30	59.20	59.20	72.80	36.40	76.17
"	24	"Quarter turn"	16.66	.....	54.17	.....	72.30	.....	24.26	77 69
"	24	Wood Flume	15.89	.....	55.40	.....	67.60	72.90	18.07	72.60
Leffel	40	Iron Case, extra finish, expressly for test	.....	.....	.....	.....	.....	.....	42.00	79.70
Common finish	30½	Wood Flume	15.40	.....	59.10	64.80	66.40	67.50	31.82	74.30
Bodine Jonval,	35	Iron Case	14.70	.....	.....	.....	.....	.....	34.00	75.90
Bryson Turret,	42	Wood Flume	14.00	.....	.....	.....	.....	.....	.....	75.14
" "	30	Iron Case	14.51	.....	.....	.....	.....	.....	26.00	74.10
Tice	30	Wood Flume	.....	.....	.....	.....	.....	.....	.....	.....
Houston	30	" "	8.50	.....	.....	.....	.....	.....	11.25	82.30
"	35	" "	15.50	.....	.....	.....	.....	.....	41.28	79.94
Second	35	Iron Case. Ice in flume and on weir	14.95	....	.....	.....	.....	.....	37.36	77.50
"	30	" " " " "	15.80	.....	.....	.....	.....	.....	26.81	78 80
Third	30	Wood Flume	15.00	.....	45.50	48.60	60.90	65.00	29.45	81.20
"	30	With four guides stopped with blocks of wood	.....	.....	.....	.....	.....	.....	22.72	76.00
"	30	With seven. or one-half, the openings stopped, discharging a little more than half water	.....	.....	.....	.....	.....	.....	15.76	70.30
Trullinger	30	Brass Buckets, bound in curb and burst	15.69	.....	.....	.....	.....	.....	19.31	50.64
Second	30	Iron Buckets. No reliable part gate	15.80	.....	.....	.....	.....	.....	27.78	70.37
Kindleberger	25		15.30	.....	.....	.....	.....	.....	25.22	62.46
Stetson	30	Open Flume—1870	15.79	.....	.....	.....	71.60	.....	25.72	78.46
"	30	In Decked Flume—1871	15.09	.....	56.84	.....	72.83	.....	26.13	79.26
Second	30	Deeper, greater discharge	16.17	.....	.....	.....	.....	.....	29.32	74.10
Same	30	Suspended by the neck	16.07	.....	55.76	.....	70.36	.....	27.17	75.70
Another	30	Like the above, with one bucket less	16.00	.....	55.41	.....	71.79	.....	29.61	77.40
Same	30	Suspended by the neck	14.76	.....	.....	.....	.....	.....	26.81	79.08
Upham	36	Wood Flume. Bound in curb & crumbled to pieces,	15 99	.....	.....	.....	.....	.....	18.32	52.08
Second	36	" " Same curb bound badly	15.59	.....	.....	.....	.....	.....	22.06	58.82
"	36	Scroll	15.85	.....	.....	.....	.....	.....	26.53	72.84
Third	36	Wood Flume. Bound in curb	15.64	.....	.....	.....	.....	.....	17.11	53.78
Fourth	36	" " Less No. of buckets than the above,	16.52	.....	.....	.....	.....	.....	18.96	60.03
Fifth	36	Scroll. Scroll 1¼ in. in depth less than the above,	16.38	.....	.....	.....	.....	.....	20.05	64 09

NAME.	Size.	REMARKS.	Ft. Head.	PERCENTAGE OF PART GATE.					WHOLE GATE.	
				1/4	1/2	5/8	3/4	7/8	H. Power	Per cent.
Sixth	36 in.	Less buckets. The 4 wheels made with plates at top	16.38	.....	.....	.....	.....	.....	20.05	64.09
Seventh	36	1st Scroll Wheel made with arms, openings between, tested in reduced scroll	16.31	.....	.....	.....	.....	.....	22.28	67.42
Luther	30	Scroll Wheel	16.10	.....	.....	.....	.....	.....	18.91	70.51
"	16	Discharged so little water that it would not carry brake	.....	.....	.....	.....	.....	.....	.....	.....
Wheeler	36		15.65	.....	.....	.....	66.90	.....	27.73	74.50
Second	36		16.10	.....	61.56	.....	70.62	.....	29.63	74.46
Third	36		15.61	.....	.....	.....	.....	.....	25.56	67.61
Whitney	30		15.28	.....	.....	.....	.....	.....	23.48	67.13
Second	30	Greater discharge	15.71	.....	.....	.....	.....	.....	23.79	.....
Third	30	Three less buckets. Results better than with more	15.66	.....	.....	.....	.....	.....	27.07	.....
"	18	Sliding gates	15.15	.....	.....	.....	.....	.....	11.70	.....
Wynkoop	42		15.12	.....	.....	.....	.....	.....	36.22	55.89
"	42	Cut hole in draft tube. Large quantity of water escaped unmeasured	10.90	.....	.....	.....	.....	.....	21.88	62.60
Davis	36	See his patent curb. Wheel burst after running a few minutes	16.30	.....	.....	.....	.....	.....	30.97	66.90
Second	36	Curb tried for part gate tests, but nothing seemed gained by the arrangement	15.17	.....	.....	.....	.....	.....	36.42	68.56
Third	36	Like the Warren	15.48	.....	.....	.....	.....	.....	33.30	63.46
Tyler	42	In use six years	15.20	.....	.....	.....	.....	.....	34.90	55.56
"	30	New, none sold	15.70	.....	38.11	.....	59.08	.....	27.13	73.83
Second	30	Old style, wrought iron buckets	15.69	.....	.....	.....	.....	.....	25.91	67.04
Third	30	Old style, cast whole, cast iron buckets	15.53	.....	.....	.....	.....	.....	25.66	67.01
Burnham	24		15.40	.....	48.16	.....	64.63	71.95	19.71	77.09
"	36¾	Tested with rigid shaft	15.27	.....	45.60	54.60	.....	71.00	42.18	78.60
"	36¾	Clutch couplings used	15.57	.....	.....	.....	.....	.....	43.27	78.50
"	36¾	Rigid couplings. Buckets and shaft filed	15.42	.....	.....	.....	.....	.....	43.27	79.20
Buzby	36		14.97	15.92	43.08	.....	58.51	63.25	24.40	66.13
Cook	30	Buckets changeable	15.70	.....	56.78	.....	67.92	.....	27.53	73.11
Second	30	Double buckets	14.71	.....	66.10	.....	74.90	73.20	28.14	72.40
Bastion	30	Intended to be like Houston's	16.25	.....	26.51	.....	48.30	.....	18.04	66.75
Second	30	Wicket Gate	16.10	.....	.....	.....	31.40	.....	27.64	69.70
Third	30	" "	16.06	.....	9.35	.....	34.60	.....	24.67	70.10

Risdon	30	With diffuser on. Diffuser was a flaring tube underneath	15.79	.....	.....	.....	.....	.....	27.53	77.09
"	30	Diffuser off	15.98	.....	37.41	.....	66.59	.....	27.42	77.14
"	36	.....	15.92	.....	41.17	58.08	69.02	76.12	36.57	78.71
Eclipse	24	Experimental to determine effect of changes	.....	.....	.....	.....	.....	.....	.....	.....
Barber	30	Combination—two wheels—test of upper wheel alone	15.97	.....	.....	.....	.....	.....	24.78	66.36
"	30	Test of the two combined	15.03	.....	.....	.....	.....	.....	26.36	68.43
Teller	30	Double wheel	14.78	.....	.....	.....	.....	.....	27.27	64.50
"	24	" "	16.11	.....	.....	.....	.....	.....	20.64	53.80
Libby	30	An inverted Houston's	15.36	.....	11.50	.....	41.42	48.88	25.78	75.61
Second	30	.....	15.94	.....	.....	.....	.....	.....	21.05	64.80
Third	30	.....	15.42	.....	.....	.....	.....	.....	27.13	77.80
Gardiner Cox	30	Double—Spiral and Jonval	14.87	.....	45.90	.....	64.30	69.50	20.11	70.00
Thompson	30	Somewhat like Houston's	15.87	.....	53.90	.....	68.90	69.10	24.50	72.00

TEST OF WHEEL TO DETERMINE LOSS OF POWER IN TRANSMISSION THROUGH GEARS.

Through a pair of Mitre and pair of Spurs, as described, the brake being placed upon the end of the second horizontal shaft, then upon the first horizontal shaft, then upon the wheel shaft.

Tests.	Head.	Revolutions.	Horse Power.	Percentage.
1st test	16.03 feet	160 per minute	26.55	75.90
2nd "	16.64 "	172 " "	27.36	74.80
3rd "	16.08 "	168 " "	26.73	77.40

OUTSIDE TESTS FOR POWER ONLY.

Chase Wheel, Orange, Mass. Have tested four different wheels, one guaranteed to give 30 horse power, gave 11.8; but as a general thing they gave about the power rated, using enormous quantities of water. The tables in their circulars are computed at about 90 per cent., and the discharge of the wheel is estimated from its openings, but the centrifugal force causes a discharge considerably larger than would pass through the wheel when it is at rest (ascertained by actual trial). The wheel under favorable circumstances gives about 50 per cent. of the power of the water used.

Whitney Wheel, at South Lancaster, Mass. Tabled horse power under 7-foot head, 66.17. Actual, as per test, 35.65.

Whitney Four-Feet Scroll Wheel, at C. B. Richmond's Mill, Lowell, Mass. Guaranteed, under 8-foot head, to give 20 horse power. Actual, as per test, under 8-foot 5-inch head, 11.22. Four-Feet Flume Wheel, same mill, 8-foot head, gave 15 horse power.

Five-Feet Blake Wheel, at same mill. Guaranteed, under 8-foot head, to give 30 horse power. Actual, as per test, under 7-foot 8-inch head, 15.

Seventy-Two-Inch Reynold's, at Williamstown, Mass. Tabled, under 12-foot 3-inch head, to give 152 horse power. Actual, as per test, 76.97. Nominal percentage, as per table, 95. Actual, about 50.

July 26, 1871, I assisted in testing the same wheel again, after submerging it. Dynamometer placed upon wheel shaft, 12-foot head gave 88.30 horse power. Saw no reason to change my opinion about the percentage of that wheel.

Breast Wheel, at North Adams, Mass. Diameter, 16 feet; length, 22; head, 14. Best result, 52.67 horse power.

I have, in the first part of my Report, alluded to tests made at Ballston Spa, N.Y., and Mount Holly, N. J. Those tests show very high results, and if the correction in Mr. Francis' formula for velocity of water approaching the weir is reliable, then low falls give proportionally much the best results. I have never seen experiments made where the brake worked so smoothly as at Mount Holly. Under the six-foot head, the wheel ran so steady that the hydraulic regulator upon the scale beam was hardly required, and when the wheel was running at its best speed, the water near the weir might have been used for a mirror, it was running so smoothly.

At Ballston Spa, Mr. Barber's wheel gave, with the upper wheel tested alone, five per cent. higher results than at Lowell; while with the two combined, the best result was about seventy-nine and a half; this was under eight-feet head. The test of the combined wheels at Lowell was not reliable, because the shaft was bound in the stuffing box. The Risdon wheel was also bound slightly in the upper bearing at Lowell, causing a loss perhaps of

one per cent., while it ran perfectly free at Mt. Holly, where it gave 84.60 as highest result. Now, it must not be understood that I consider the Risdon or Barber wheel exceptional, for that is far from being the case, for I believe the other wheels tested would show the same proportional results under low heads, and to determine that point, I shall immediately construct a new Flume that will enable me to test all wheels under from six to eighteen-foot head, and I propose to have my flume large enough to test five-foot wheels. I test wheels that give good percentage that I should not consider so good for practical use as others that perhaps show in my Report less favorably, but it is not expected that I should discriminate, but give figures only, as I do, but it is for the interest of those using wheels that a matter of such importance should be definitely determined; for that reason I make the following proposition: The first day of September next I will have Flume and apparatus complete for testing large wheels under varying heads, the trial to be open to all, each wheel-builder to furnish one or more forty-eight or fifty-inch wheel, to be delivered at my Flume upon the day named, and each party to be there ready to choose a committee competent to examine and witness the test of each wheel, and let the decision of that committee be published throughout the country; and I here call upon the Messrs. Swain, Leffel, Bodine, Bryson, Houston, Stetson, Burnham, Libby, Risdon, Wheeler, Cook, Tyler, Barber, and others, to demonstrate by a thorough competitive trial, where the conditions are the same for all, that they have faith in their assertions that *their wheel is the best.*

Particulars for terms, conditions, &c., may be had upon application.

JAMES EMERSON,

Box 502. Lowell, Mass.

February 1st, 1872.

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